Advisory Committee For Hirakund Dam Project 1948

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CONTENTS

	PAGE
1. Letter of Submission	1
2. Summary of Recommendations	2
3. Part I	5
4. Part II	11
5. Part III	17
ENCLOSURES—	
1. Note by Shri A. N. Khosla, Consulting Engineer with the Government of India, dated 12th May, 1948.	31
2. Note on the Suspended Sediment Load of the Mahanadi River at Sambalpur during 1947 by Dr. R. C. Hoon, M. Sc., Ph. D., Officer on Special Duty.	34
3. Probability Curve, Flood Moderation Curves	37
4. Longitudinal Section along the centre line of the dam.	38
5. Lay out plan of the dam and appurtenant works.	39
6. Section of the concrete dam.	40
7. Note on the suitability of soils for the construction of the Earthen portion by Dr. R. C. Hoon, M. Sc., Ph D., Officer on Special Duty.	41
8. Sections of Earthen Dams.	44
9. Statement of comparative quantities of work to be done.	45
10. Programme of work.	46
11. Statement showing the rate of contribution and water rate per acre in the sanctioned projects in the State of Mysore.	47
12. Note on Land Compensation under Krishnarajasagar Reservoir.	48

FIGURES.—

1. Pictorial representation of the Power Channel, Hirakud Dam.
2. Typical Daily and Weekly Load Curve, Summer months.
3. Typical Daily and Weekly Load Curve, Winter months.
4. Typical Daily and Weekly Load Curve, Spring months.
5. Typical Daily and Weekly Load Curve, Autumn months.
6. 60% Load Factor Curve.
7. 50% Load Factor Curve.
8. Factor for dividing cusecs×head for killowatts.
9. Probable efficiency curve of water turbines.
10. Longitudinal Section of the Power channel.

Copy of Government of India, Works, Mines & Power Ministry letter, D. W. 106(112), dated, New Delhi, the 12th March 1948, addressed to the Chairman, C.W.I.N. Commission, appointing the Advisory Committee for Hirakud Dam Project.

"SIR,

I am directed to say that, as the execution of the Hirakud Dam Project would involve an expenditure of the order of about Rs. 48 crores, the Government of India have, in consultation with the Government of Orissa, decided to set up a high level Committee for a period of two months from the first week of April to give advice to the Central Waterpower, Irrigation & Navigation Commission on the Project in general and its technical and other features. This Committee will consist of Dr. J. L. Savage, Consulting Engineer and international authority on dams, Mr. L. N. McClellan, Chief Electrical Engineer of the United States Bureau of Reclamation, Mr. Narsimhayya, Chief Engineer, Mysore, and Mr. S. A. Gadkari, Chief Electrical Engineer, East Punjab. Sir M. Visweswariya will also be associated with this Committee in an advisory capacity. It is hoped that the Committee shall meet in the first week of April and conclude its work in about 6 weeks. All necessary preliminary arrangements connected with the construction of the Hirakud Dam, should, meanwhile, be proceeded with.

2. I am also to convey the sanction of the Government of India to an expenditure of Rs. 70,000 in connection with the above Committee as detailed in the annexure (*not included*) to this letter. The expenditure should be debited to the capital cost of the Hirakud Dam Project. Necessary dollar facilities to the extent of $ 14,000 will be available as and when necessary.

I have the honour to be,

SIR,

Your obedient servant,

(Sd.) S. NEELAKANTAM.

Deputy Secretary to the Govt. of India "

To

The Chairman,

Central Waterpower, Irrigation and Navigation Commission.

Dear Sir,

We are submitting herein our report on the Hirakud Dam Project, the first of the works in the plan for unified development of the Mahanadi Valley, Orissa Province. The site was inspected by Dr. Savage in March 1947 and by Messrs. Narasimhaiya and Gadkary in April 1948. We have examined the data placed before us and our report is based on it.

The Committee appointed by the Government of India comprised Dr. J. L. Savage, Mr. L. L. McClellan, Mr. M. Narasimhaiya and Mr. S.A. Gadkary. Unfortunately Mr. McClellan was unable to join us due to his preoccupations in the U. S. A. The comments on the irrigation and general aspects are mainly by Mr. Narasimhaiya and on hydro-electric portion by Mr. Gadkary.

In the preparation of the report we have worked in close collaboration with Mr. A. N. Khosla. We are very grateful to him for all the help he has given. We are happy to record that he is in general agreement with our recommendations and the modifications made in the original proposals.

The help of the Central Waterpower, Irrigation and Navigation Commission organization was fully available to us and we are specially grateful to Mr. R. P. Vasishth, the Project Officer, and his staff for the valuable assistance rendered to us particularly by Mr. M. B. Rangaswamy who was on the preparation of the project and of the various appendices attached to this report.

In our considered judgment this is a project that should be started atonce and pushed through to completion in view of the great potentialities in it for increased food production and industrial expansion.

Yours sincerely,

(J. L. SAVAGE),

(M. NARASIMHAIYA),

(S. A. GADKARY).

NEW DELHI,
The 20th May, 1948.

SUMMARY OF RECOMMENDATIONS.

1. For the design of the reservoir for flood absorption the recommendations of the Consulting Engineer with the Government of India as made in his note dated the 12th May 1948 (Enclosure 1) be adopted.

2. The silt observations of 1947 having given higher figures of silt load than assumed in the project report, the silt reserve as now recommended by the Consulting Engineer be adopted and the dead storage level be fixed at 590·0 accordingly.

3. Taking the flood reserve and silt reserve as under items 1 and 2 the maximum reservoir level will be R. L. 625·00 (adequate for 100 year flood) and this may be fixed as the reservoir level. The lands coming under submersion will be acquired up to this level.

4. A free board of 10 feet be allowed above R. L. 625·0, the top of the dam being R.L. 635·0. A parapet 4 feet high be provided all along. In the case of 1,000 year flood and 10,000 year flood the free board will be encroached to the extent of 5 feet.

5. The regulated flood of 780,000 cusecs should be arranged to be disposed of through deep set sluices adding 10% to 20% extra capacity for gates under repairs, etc.

Two siphons of Ganesa Iyer Volute type be put in as an experimental measure.

6. The difference of regulated flood between the 10,000 year and 100 year floods, i.e. 830,000 minus 740,000 cusecs should be provided for through emergency spillway siphons including Ganesa Iyer Volute siphons.

7. The main dam in the two branches of the river to be of concrete, the right section (which will provide for the necessary penstocks for the power house, locks, fish ladder etc.) will be 1,570 feet and the left section (housing the deep set sluices) will be 2,475 feet.

8. The main dam on the Kolarikud and Hirakud islands including the deep section in between to be of earth. The remaining length on the left bank will also be of earth. The lengths will be 6,725 and 4,165 feet respectively.

9. The sections of the concrete and the earth bund for the main dam as designed be adopted.

10. The dykes should be of earth as designed ; precautions for cut off and creep walls being taken where the depth of water exceeds 25 feet.

11. The modified proposals of Mr. Khosla for the power channel be adopted, as they result in economy and efficiency of power operation.

12. Pending detailed surveys of canals and further investigation, the proposals for irrigation made in the project report be adopted. Under lift irrigation, however, the provision for ⅓ of the proposed area in the first instance, or say 1,00,000 acres be made in the estimate. The location and the manner in which this is to be planned to be fully investigated.

The storage in the reservoir earmarked for irrigation will remain unaffected.

13. The duties proposed for different crops be adopted.

14. The water rates proposed in the Project Report may be adopted—the position being reviewed at the end of 5 years after irrigation commences.

15. In view of the magnitude of the problem and the period of six years fixed for the completion of work, the question of resettlement and rehabilitation of people that will be dispossessed by submersion of their villages and lands to be taken up atonce.

16. Steps for overhauling the delta irrigation in the Mahanadi Valley to be taken up atonce as also the investigation to utilize the continuous supply of 8,000 to 10,000 cusecs in dry weather for extension of rabi crop cultivation and bringing new areas under irrigation.

The proposal of Sir M. Visveswaraya to divert Mahanadi waters to the Chilka Lake with the possible generation of power and irrigation of large tracts in the southern belta should be fully investigated.

To achieve these objects expeditiously a special division under the Central Waterpower, Irrigation and Navigation Commission should be immediately constituted.

17. Soil surveys in irrigated areas must be carried out soon for purposes of crop planning.

18. Malaria surveys in the area should be conducted to prepare schemes for preventing increase of malaria incidence.

19. The present laboratory set up in connection with investigations should be expanded to deal with soil materials, aggregates, cements and concrete.

20. The questions such as soil conservation, fish culture, industrial survey, agricultural survey should receive attention as a part of the multipurpose development.

21. For the development of irrigation in kharif and rabi seasons, the Development Committee should pay attention to organize propaganda for better cultivation, research station, agricultural farms, demonstration plots in representative areas.

22. The question of the levy of water rates and payment of part of additional profits by tenants in lieu of betterment tax should be studied.

23. Immediate steps should be taken to set up an organisation for preparing specifications, details of design, working out schedule of quantities for power house and grid substation equipments, etc.

24. Preparation of papers for calling tenders for power house machinery, switch-gear, transformers, etc. should be taken in hand early.

25. Design of towers and other structures for extra high tension lines should be undertaken.

26. Steps to be taken to make arrangements for the manufacture of towers for different voltages in this country.

27. Installed capacity of six units of 37,500 KW in Power House No. 1 and four units of 24,000 KW in Power House No. 2, giving maximum primary power of 2,18,000 KW may be catered for, while the secondary power should be generated and the necessary machinery and equipment installed only after the primary power is booked for sale.

28. Local distribution work should be undertaken by Government as it is a very profitable concern. Therefore, necessary cost may be provided for in the project.

29. The navigation question should be taken up atonce and investigations of the Dhamra Port pursued with vigour.

30. The staff engaged on this scheme should be given special concessions in the shape of construction allowance, rent free quarters, etc. in view of the arduous nature of the work.

31. The programme of work to complete the work in six years be adopted. Month by month programmes for these years, should be worked out, before October 1948, so that a basis may be readily available for the building up of a suitable and adequate organisation and collection of equipment.

The project as envisaged should be started atonce and pushed through with vigour to completion as it will usher in an era of incalculable benefit to Orissa and open up a vista of great possibilities of industrial expansion and increased food production.

(J. L. SAVAGE),

(M. NARASIMHAIYA),

(S. A. GADKARY)

PART I.

Runoff.—The catchment area of the Mahanadi at the site of the Hirakud Dam is 32,200 square miles. As per tables furnished in Professor Mahalanobis's Reports, it lies in M3, M4 and M5 zones, the annual rainfall characteristics of which are given in the following table :

	M3	M4	M5
Annual rainfall—			
Mean	59·50″	53·14″	47·59″
Maximum	70·22″	62·85″	55·25″
Minimum	51·90″	50·72″	40·72″
Maximum rainfall on any day	6·01″	7·46″	4·63″

The runoffs at Hirakud have been derived from the calculated runoffs at Naraj. They are maximum 69·40, mean 50·00 and minimum 20·61 m.a.ft. Shri A. N. Khosla has evolved a formula connecting precipitation, temperature and runoff for any catchment. Checked against actuals, the formula seems to be good for universal application.

Maximum flood.—The usual flood formulae to arrive at the maximum flood discharge include certain coefficients and indices which are at best speculative. The results derived from them can, therefore, be only approximate. Fortunately discharge observations have been taken at the Naraj site and are available for a period of 80 years. The maximum flood discharge at this site occurred in the year 1834 and is computed to be 1,570,000 cusecs. Applying the formula $Q=KM^{\frac{3}{4}}$ to obtain the corresponding discharge at the Hirakud dam site, the discharge at the latter site works out to

$$Q_{Hirakud} = Q_{Naraj} \left\{ \frac{M_{Hirakud}}{M_{Naraj}} \right\}^{\frac{3}{4}}$$

$$= 1,570,000 \left\{ \frac{32,200}{51,000} \right\}^{\frac{3}{4}} = 1,110,000 \text{ cusecs.}$$

It has been found that in several valleys the calculated maximum discharge has been far exceeded by peak discharges. The design of flood disposal works at Krishnarajasagar and Mettur had to be completely revised on account of 1924 floods in the Cauvery which far exceeded the calculated maximum flood and any flood that had been exprienced before.

Accordingly flood studies have been made for 1,000 and 10,000 year floods vide Mr. Khosla's note dated 12th May 1948 (Enclosure 1).

Silt reserve.—In the project report the dead storage level was fixed at 580·00. Silt observations are being conducted for the last 1½ years and the report thereon is enclosed (Enclosure 2). The Consulting Engineer has made a special study of this problem and a note prepared by him in this matter is given in Enclosure 1. He recommends that the dead storage level should be kept at 590·00 giving a dead storage capacity or silt reserve of 2·24 m.a. ft. This would, on a conservative basis, make the reservoir function for 100 years without impairing its useable or live storage. With the provision of deep set sluices, it will be possible to allow a greater proportion than 50% of the silt through. The siltage per annum in the reservoir would thus be greatly curtailed, and the useable storage in the reservoir maintained in full for more than 100 years.

Flood reserve.—The floods in the Mahanadi have caused considerable damage to life and property in the delta.

Considerable data of the discharges at Naraj has been collected by Prof. Mahalanobis. The question has been examined by the Orissa Floods Enquiry Committee constituted under the advice of Sir M. Visvesvaraya as a result of his inspection of the delta. In Appendix 2 of the 1938 Preliminary Report of the Orissa Floods Advisory Committee, Mr. Shaw says that to save lands and property in the delta from damage, it is necessary to keep the gauge at Naraj at 89·00. From a consideration of the highest floods that have occurred in several years, he came to the conclusion that provision should be made for about 7½ to 8 days to absorb the extra discharge over what is connotted by the gauge 89·60 at Naraj. This quantity, he calculated at 144,000 m.c. ft. or 3·3 m.a.ft.

The question of flood moderation has been examined in detail in Mr. Khosla's note (Enclosure 1) and the following are the relevant data for purposes of determining the flood reserve and reservoir level :

Regulated flood (cusecs) 1	Flood reserve (m. a. ft.) 2	Silt reserve (m.a.ft.) 3	Reservoir capacity (2+3) (m. a. ft.) 4	Reservoir level Ft. 5	Corresponding gauge at Naraj Ft. 6
		100 years flood.			
780,000	3·74	2·24	5·98	625	90·2
740,000	4·51	2·24	6·75	630	89·8
		1,000 years flood.			
770,000	4·52	2·24	6·76	630	90·3
		10,000 years flood			
830,000	4·49	2·24	6·73	630	90·8

Flood moderation graphs are given in Enclosure 3.

In the case of a 100 year flood, a reservoir level of 625·0 will give a corresponding gauge of 90·2 at Naraj which is slightly above 90·1 the assumed safe gauge. We consider that R. L. 625·0 should be taken as the normal reservoir level. Lands coming under submersion should be acquired to this level.

In the case of a 1,000 year flood the reservoir level can be allowed to rise to R. L. 630·0 with a corresponding gauge of 90·3 at Naraj. For the 10,000 year flood with a reservoir level of 630·0, the Naraj gauge will rise to 90·8. A gauge of 90·3 at Naraj will be only slightly above the safe gauge of 90·1 and can be accepted without hesitation for a 1,000 year flood. A gauge of 90·8 will be on the danger side but the probability is once in 10,000 years and this risk will be permissible. It must, however, be pointed out that with the regulated flow secured by the construction of the Hirakud Dam, the channel regime will improve and a lower gauge reading at Naraj can be reasonably expected so that the possibility of serious damage becomes remote.

Free board.—In view of the above, it will be enough to fix the top of the dam at 635·00. This will give a free board of 5 ft. in 1,000 and 10,000 year floods and nearly 10 ft. in a 100 year flood as also under normal reservoir conditions. A parapet of 4 ft. above top of dam is recommended. This free board will take care of heavy wave action.

Disposal of controlled floods.—The maximum controlled flood discharges below the Hirakud Dam, will be 740,000, 770,000 and 830,000 cusecs for the 100, 1,000 and 10,000 year floods respectively.

The suspended silt has a great manurial value and the delta areas depend mostly for their fertility on this silt. It is quite essential that suitable provision should be made for ensuring this. The manner in which the delta would be affected by the construction of a reservoir should be studied. There are some areas that depend for irrigation on inundation channels. The interests of the prolongation of the life of the reservoir require that at least 50% of the silt should pass below the dam. As pointed out by the Consulting Engineer this object will be best secured by providing for flood discharge through deep set sluices. In the execution of the scheme, which comprises the bunding up of a river of a width of 3 miles, such an arrangement will offer great facility for diversion of stream flow.

The discharging capacity of the sluice gates should include 10% to 20% of the above flood discharge, to allow for some gates being out of action for repairs, etc.

The difference of regulated discharges between the 10,000 and 100 year floods namely, 830,000 and 740,000 cusecs should best be provided for through emergency siphons (including the two Ganesh Iyer Volute siphons) with sills at 628·00.

Site.—The capacity of the reservoir at R. L. 625·000 or 125 ft. above river bed is 5·98 m.a.ft. This is compared with some other sites in India as noted below :

Reservoirs	Height of dam above river bed (ft.)	Capacity	
		m. c. ft.	m. a. ft.
Mettur	176	95,660	2·20
Krishnarajasagar	130	48,335	1·11
Lloyd Dam	190	24,198	0·56
Lakkavali Dam	185	61,250	1·41
Bhandardhara Dam	270	12,894	0·30
Nizamsagar	115·5	35,066	0·81
Hirbhasagar	100	27,000	0·62
Vanivilassagar Dam	142	30,000	0·69
Hirakud Dam	135	258,000	5·98

Dr. F. A. Nickell, Consulting Geologist, U. S. A. inspected the site and his report forms Appendix II (*vi*) of the Project Report. He says " Fully 70% of the rock beneath the proposed dam is granite gneiss, much of it in massive bodies. Below the surficial zone of alteration and especially in the river channel where the concrete structure is planned, all the rocks are extremely hard and far surpass the physical qualifications demanded of a foundation for a dam of the indicated size ". " Nearly three quarters of the valley floor along the proposed site of dam is composed of granite gneiss in massive bodies intrusive into ancient schists and phyllites. Extensive bed rock exposures show unusually satisfactory foundation rocks and it is obvious that suitable rock will be found at shallow depths throughout the

length of the main dam including the abutments ". Extensive borings with diamond drills confirm this. The results are indicated in the longitudinal section (Enclosure 4). The depths where fresh rock is met with are plotted.

The width of the river at the site selected is about 3 miles. But in this width there are two islands dividing the river into two main branches and one minor. While the level of the bed of the river is R. L. 500 the average level of the Hirakud island is 540 and that of Kolarikud island is 535. These two islands are separated by a relatively deep section of 1,200 feet width. The length of the main dam as per alignment slightly modified comes to 15,727 ft.

A layout map is enclosed (Enclosure 5). It is porposed to have concrete dams across the two branches of 1,570 ft. on the right side and 2,475 feet on the left.

The deep set sluices and the emergency spillway will be located in the left dam section. The power house will be located in the right section of the dam. The length of the dam at this end will be more than adequate for locating the structures connected with switch yard power house, scouring sluice, navigation locks and fish ladder.

The islands Kolari kud and Hirakud are advantageously placed in so far as they separate the power house section of the dam from the spillway section. The total length of this high ground including the deep section in between is 6,848 feet. To get the best value of the natural features of this site the axis of the dam should be moved slightly upstream on the right abutment keeping the point on the left abutment fixed (as per Enclosure 5). This will also ensure economy in the concrete as well as the earth sections of the dam.

The new proposal of Mr. Khosla of using the two miles of the river channel just below the power house section of the dam as part of the power channel by bunding it off from the main river offers the advantages of substantial saving in first cost, a balancing reservoir at the head of the power canal and a desilting basin.

Design of Dam—(*a*) *Concrete Section.*—The design for the concrete section for sluices and spillway siphons is based on standard practice (Enclosure 6). In view of the rocky nature of the site in general and the dam being founded on fresh rock the keying will be generally of the order of 10 ft. The sills of the sluices may be kept at about R. L. 510·0 so that the discharge will flow along the bed of the river which in this section happens to be all rocky for long distances. The protective works, if any, will be comparatively simple. Model studies are recommended in this connection.

The aggregate material required for concrete is said to be available in adequate quantities

(*b*) *Earth Section.*—Soil analysis has been made on samples of earth material available in the locality (Enclosure 7). This material is admirably suited for the construction of an earthen dam both for the impervious and semi-pervious zones. The field investigations are rapidly going apace for finalising the borrow areas at economic distances. Taking into consideration the earth materials available in the locality the proposed designed section is quite suitable. Some typical sections of similar bunds built in India, including C. P. and Mysore are attached (Enclosure 8).

With modern methods of laying the earth in 6″ layers, the use of optimum moisture and consolidation with sheepfoot rollers, the earth attaining wet and dry densities of 114—133-lbs. and 104—117-lb. per c. ft., respectively there can be no question about the safety of the bund.

So far as the white ant problem is concerned, it might be stated that in similar locations in Mysore State where bunds of hundreds of tanks big and small exist there has not been any instance in the experience of Mr. Narasimhaiya, of conditions becoming insecure on account of white ants or rodents. No special precaution is therefore considered necessary in this respect.

At the junctions of the concrete and earth sections measures should be taken against creep, etc. The impermeable core will be 190′ thick and the insertion of creep walls and cut-off walls will make these junctions perfectly satisfactory.

(*c*) *Dykes* —There is a considerable stretch of low ground on either side of the main dam section. This will be bunded up with dykes of suitable height. On the right side the low level stretch is continuous and the length is 36,000 ft. The depth of water against the dyke in this reach will not exceed 25 ft. Along the left dyke the low ground is in separate sections; the total length of these is 32,700 ft. Except for two small lengths where the depth of water will be 74 ft. and 65 ft. respectively, it will not exceed 25 ft. in the rest of the length.

In view of the length of the dykes found necessary on account of the configuration of the country, the design provides for a top width of 30 ft. and side slopes and thick rock fill as for the main dam, while ordinarily a much lighter and more economical section would have been adequate. The top of bund will form the approach road to the work from Jharsugudda. As in the case of the main dam, no special measures against white ants or rodents are required in the case of dykes.

A 1,000 ft. width of land along and in the rear of the dykes should be acquired and reserved for borrow pits.

Similar dykes or banks extending over many miles made of sand and loose earth are quite common in Northern India as marginal embankments of low dams, or barrages, canal banks, flood banks, etc. and have stood for years without trouble. The dykes at this place with the conservative design and special features mentioned above need cause no concern whatsoever.

Power channel.—According to the proposal in the project report the tailrace of the first power house was to be through a channel taking off from the rear of the power house. This involved heavy and very expensive cutting in earth and rock in the headreach down to the Sambalpur Bargarh road. Similarly, the tailrace for the second power house down to the river, involved heavy cutting mostly through rock along a length of 10 miles. Mr. Khosla has since worked out a satisfactory and economical alternative to isolate the left branch of the river downstream of the dam by bunding it off from the nose of the Hirakud island to the high ground on the right bank and the whole alignment has been made with an eye for efficiency and economy. The power channel proper would take off from the junction of this bund and the high ground, thus saving 10,000 ft. length of excavation in difficult country and securing at the same time a pond that will come in useful for the operation of the power house. A suitable section of the bank should provide against flood backwaters.

The further alignment passes through much easier country. At 7,000 ft. along the power channel advantage is taken of a depression for forming a second pond by construction of bund of suitable section. The further section of power channel is in usual contour cutting till it meets the subsidiary reservoir formed by a dam 75 ft. high.

The latter dam will be of concrete for a length of 1,000′ to house the penstocks, locks, etc. and of earth for a length of 16,580 ft. The tailrace water will be dropped in to the river immediately below the power house and the length of 10 miles of tailrace channel (with its heavy rock excavation) provided in the original project report avoided.

Estimate.—The approximate cost given in the project report had been based upon the rates prevailing in December 1946. Quantities of main items of work on the modified proposals for the main dam have been taken out. The comparative statement (Enclosure 9) shows the variations from the figures in the project report. It will be seen that except for

rock fill there has been no excess in respect of the other items. Some increase in the provision on certain minor items such as anti-malaria operations and sanitation may be needed.

For special tools and plant a lumpsum provision of 50 lakhs has been made. According to the programme laid out (referred below) the quantities of work to be done per day both in respect of concrete and earth work require a large scale mechanical equipment. The lumpsum provision may be exceeded. But after the completion of the Hirakud Dam whole of this equipment will be available for use on other projects now under investigation.

There has been a heavy fluctuation in rates which are ever on the increase. After the works proceed for a year or two and when conditions get stabilised on the dam work the position may be reviewed and revised estimates got prepared. In our view no useful purpose will be served in preparing fresh estimates now as they may be too approximate at this stage.

Programme of work.—A tentative programme has been drawn up to complete the Dam work in a period of six years (Enclosure 10). Taking 200 working days on a conservative basis in view of the heavy rainfall in the three monsoon months and high temperature conditions in May and June the maximum daily progress on concrete and earthwork works out to 50,000 c. ft. and 50,000 cubic yards respectively. This target will have to be achieved and kept up from the second year of the work *i.e.* 1949-50. It is necessary, therefore, that the mechanical equipment needed should be obtained well in advance.

Detailed programme month by month on all items should be prepared and work schedule drawn up for guidance in execution and building up a suitabe and adequate organisation and equipment.

It is possible to generate power at the Power House No. 2 in the first instance even before the reservoir is fully formed. The power channel, the banks and the subsidiary dam works have to be commenced simultaneously with the main dam.

Arrangements for obtaining tenders for the supply of Deep Set Sluice gates should be immediately made.

PART II.

Irrigation.—The storage between 590·0 and 625·0 *viz.* 3·74 m.a.ft. is proposed to be utilised to the best advantage for increasing food crops and generation of power.

The working table prepared for the average year 1938-39 has taken into account the requirement of full irrigation as envisaged in the project, the loss by evaporation and the draw for power generation. Evaporation losses have been taken on a conservative basis judged from provisions made for other reservoirs. Monthly losses adopted for the Krishnarajasagar reservoir are shown below :—

January	3·80″
February	4·0″
March	5·00″
April	7·00″
May	8·00″
June	4·25″
July	3·80″
August	3·80″
September	3·80″
October	3·80″
November	3·80″
December	3·80″
Total	54·85″
Figure adopted for Hirakud	72·00″

While at Krishnarajasagar the rainfall in the monsoon season is much less than at Hirakud reservoir, the temperatures in the Krishnarajasagar in the hot weather are much less than the temperatures in the Hirakud reservoir (The figures for Krishnarajasagar were obtained after joint observation at Krishnarajasagar by Mysore and Madras Engineers with reference to regulation according to the terms of 1924 agreement).

No detailed surveys have yet been made for the canals. The commanded areas and those proposed for irrigation have been worked out from the rough alignment on the topo sheets. The total commanded area is 1,313,000 and area proposed for irrigation 875,210 acres. The flow irrigation extent comes to 494,710 acres and the lift irrigation, 380,500 acres.

Judging from the configuration of the country particularly on the right side the areas assumed for irrigation out of the commanded area can be secured and if any deficiency occurs this can be easily covered by extending the canal by a few miles.

It is seen from the provisions made for earth work in the estimates that the right lift canal is the most costly. The extent of irrigation under it is 290,000 acres. The lift is 150 feet. In the project report it has been indicated that this requires examination. The lift irrigation may be limited in the first instance to about 1/3rd the area or say 100,000 acres in the estimates. This provision must be available so that possibilities of lift irrigation whether by contour channels lifting the water by stages of say 50′ or by direct pumping from flow canals with separate installations all along may be fully maintained.

Power that would be released on account of this reduction could be marketed at higher cost of Rs. 120 per k.w. as against Rs. 20 per k.w. assumed for lift irrigation.

In the Rabi season the duties being high the flow canals will not be running full, and such a condition can be expected in October, November and December also. The upper marginal lands could be supplied with water during these months till the end of May from the main

canal itself by lift by running it to the full capacity. This proposition seems feasible. The much needed water in the tail end of kharif season may be supplied to certain rain fed lands, but the availability of water for irrigation in the dry season from January to May will be greatly appreciated for growing commercial crops. Lift irrigation is likely to prove very popular for such a purpose.

Duty.—This is a region of fairly heavy rainfall of 45-50″ per annum, most part of which precipitates in the months of July, August and September. The conditions are similar to what obtain in Malnad Region of the Mysore State. The tract is hilly there; here the country is comparatively flat. A good proportion of this land is grown with paddy which depends upon this rainfall. The harvesting of this paddy is in the month of November. The paddy flats have all been formed in good terraces and individual fields are of large sizes, the bunds of these being kept in certain cases even 3 feet higher than the level of the plots. Water for irrigation in the canal will be required if at all very occasionally in the monsoon months of the year and to some extent in the months of October and November.

In the delta where the duty is said to be 67 for paddy, the canal distributaries and field channels are in a deplorable condition. Water is taken through cuts, the canal is badly silted up and there are no suitable locking arrangements. Further the soil is sandy. There is heavy wastage of water.

Water requirements have been calculated month by month and the duties are evolved. The proposed duties are reasonable and may be adopted and similarly also for other crops.

With the irrigation facilities during the break periods in the rain weather and in the months of October and November the production of paddy per acre is estimated to increase by about 25%.

The percentages of different crops assumed, 70 for paddy and 30 for other crops, are only tentative. The detailed soil analysis in the irrigated tract which must be taken up at once will indicate the nature of crop planning. From a general enquiry it is ascertained that soil is suitable for sugarcane, cotton, wheat, citrus fruits, etc. The establishment of a sugar factory in the area will give an added impetus to the growth of sugar-cane cultivation. It can be safely assumed that water will be used to a much greater extent for the rabi crops. In this populous tract the development of such crops will be on an intensive scale. Propaganda, facilities by Government in the shape of loans, supply of artificial meanures and agricultural equipment and standard demonstration plots and such measure undertaken all over the area in a vigorous manner will lead to a rapid development. The opening up of agricultural research station and government farms where experiments on different crops are conducted will go a long way to encourage such cultivation. As there will be much keener demand for water in dry weather from January to end of May and they can grow commercial crops the percentage of 30% assumed in the project for crops other than paddy can easily go up to 50%.

Water rates.—The question of water rates in this tract very largely depends upon the land revenue policy which is in existence from a long time. The assessment is very low and the rates of assessment on wet lands depending upon rainfall and on canal water in the delta are comparatively lower than obtain elsewhere, as has been brought out in the project report.

There can be no two opinions that when irrigation facilities are provided to overcome the uncertainties and vagaries of rainfall and water supply is guaranteed to crops year by year, and when additional advantage of better yields and for growing commercial crops is afforded, the tenants must pay a portion of the share of additional profits to the state.

This is mainly a question for the local administrators to examine thoroughly after a study of the conditions obtaining in the neighbouring provinces and states and evolve a

suitable rate schedule for the different crops that will be made possible by the canal irrigation by water stored at heavy cost.

Judging from the rates that obtain in the Mysore State under the several projects, as detailed in the enclosure (Enclosure 11) from which a few items are extracted below there can be no question that the rates proposed in the project report are if anything on the low side.

	Water rate Rs.	Contribution Rs.	Rainfall inches.
Anjanapur	8	50	30—35″
Byramangala	6/8	100	25″

The rates that will be levied should be reviewed at the end of five years period from the date of supply of canal water and revised with due consideration of benefits that would be derived from this project both in respect of additional yields and the improvement in cost of lands.

Resettlement.—By the formation of the reservoir, 153 villages and 150,000 acres of which 75,000 acres are cultivated lands come under submersion. The work of resettling and rehabilitating the dispossessed people is a large problem, that requires very energetic and sympathetic handling.

A copy of the note on the measures taken in Mysore for the rehabilitation and resettlement of people dispossessed by the formation of the Krishnarajasagar reservoir is enclosed (Enclosure 12). An elaborate procedure was adopted in this behalf and instead of cash compensation, land was given in exchange. This problem is obviously the special responsibility of the Orissa Provincial Administration. But, we strongly feel that the CWINC organization which is responsible for the unified development must share the responsibility. The Chief Engineer of the Mahanadi reservoir should have an abiding interest in dealing with this problem. From a psychological point of view this is essential, and the sooner the sympathies of the people that are affected by the submersion of their villages and lands are secured by this organization, the better it is for an easy progress of the works in general.

It is easier for the CWINC organization on the Hirakud Project to develop model villages in areas that are to be allotted to the dispossessed people rather than for the organization that may be set up by the Provincial administration. In fact, this portion of the work has to be a special charge on those that are responsible for the formation of the reservoir.

It is stated that suitable forest areas in States that have recently become merged in Orissa are available for settlement. The work of resettling can immediately start as in this region of heavy rainfall paddy cultivation can be developed atonce pending the provision of irrigation facilities.

Though it may be superfluous to mention, it is necessary to provide these new villages with all amenities, such as protected water supply, wherever possible electric power at the lowest rates, educational institutions, dispensaries, health centres for groups of villages, etc. The formation of such villages and settlement of villagers fairly well in advance of the storage in the reservoir and consequent submersion, will go a long way in confidence being created in the people of the tract whose co-operation for development is essential.

Delta Irrigation, Mahanadi Valley.—The unified development of the Mahanadi Valley has to take into consideration the present condition of the delta irrigation. The probable effect of the construction of the reservoir on the delta has to be studied. Emphasis has been laid very rightly in the project report (pages 19 and 52) on these aspects.

According to the administration report (Irrigation) of Orissa Province for 1944-45, the total extent of irrigated areas including hot weather is 190,821 acres (page 28).

An inspection of a representative area of the delta showed that the main Canal, distributaries and field channels are all in a deplorable condition. Water is taken through cuts in distributaries and there are no regulating arrangements for supply to the fields. There is considerable waste and tail end lands naturally suffer or are out of cultivation. Rigid economy of water is called for.

There will be a perennial flow of 8,000 to 10,000 cusecs that will be let into the river from the Second Power House when the Hirakud Reservoir starts functioning. This can be utilised (*i*) for obtaining large extents of lands in the present irrigated area for rabi cultivation, and (*ii*) for bringing fresh large areas under cultivation (possibly one million acres).

We wish to emphasise that these aspects of development in the delta assume importance as great in magnitude as the features of the Hirakud Dam Project itself which affords irrigation facilities to Sambalpur district only.

Great advantage that will accrue will be that immediately the power house functions the water is available for utilization as noted above.

From these considerations, it is imperative that (*i*) action to set the present canal system in order on a five year programme of work should be taken immediately, (*ii*) investigation should be set up for the utilization of the 8,000 cusecs that become available in the dry weather.

A special division, as a part of the CWINC organization, should be set up atonce for the above two objects and later on when the estimates are ready under (*ii*) a Circle for the execution of the schemes that might have to be taken up has to be constituted.

This scheme should form an integral part of the Mahanadi Valley Development both in respect of expenditure and returns and incorporated in the revised project when prepared.

The proposal of Sir M. Visvesvaraya to divert part of Mahanadi waters to Chilka Lake with the possible development of power and of irrigation in southern delta should be immediately re-examined. This item of work also should be the responsibility of the new division.

General—In connection with the envisaged starting of new industries near the reservoir, it will be desirable to acquire adequate areas on the right side for an industrial centre. This will be in addition to what may be required for the building up of a construction colony which would later develop into a town.

Anti-malarial measures on an intensive scale should be taken up atonce in the colony areas on the left and right banks immediately. These are essential in the interest of the expeditious progress and adequate staff for the purpose should be put on the ground forthwith.

In the case of works of large magnitude the success depends to a large measure on the conditions under which the personnel work. The site of the dam is in an area where the rainfall is heavy in the monsoon season and this will be succeeded by a period of malaria incidence. The summer conditions, when the works are to go on at a maximum speed, are very exacting the temperatures in the shade going over 110°. The programme drawn up is to complete the scheme in six years. This imposes a very heavy task and unless work proceeds from the commencement to the end at top efficiency, the anticipated result cannot be achieved. Best of men in all categories have to be employed and their whole-hearted work and co-operation ensured and secured. While no doubt the patriotic zeal of the staff for putting in their best for this first work of magnitude undertaken in free India, can naturally be counted upon, the Government on their side have to sympathetically consider the measures that may be necessary to create enthusiasm in the staff.

It is permissible to say what was done in Mysore and what still obtains in respect of such works. The special work Vanivilas Sagar was started in the early nineties, the Kirshnarajasagar in 1910 and now several other comparatively smaller schemes all over the state and the last of them to be completed was the Mahatma Gandhi Hydro-electric works (Jog). Special concessions and facilities were granted to the staff on these works.

The living conditions under the Jog scheme were very exacting, the region being in a malaria ridden tract of 200″ rainfall. Free quarters and free light and water were provided, 30% of pay was given to all as construction allowance. For the lower staff a minimum pay was fixed. Anti-malaria operations were undertaken on an intensive scale in the colony medical assistance provided along with other social amenities. In a similar manner, these facilities are provided on all such schemes now in progress, the rate of allowance ranging from a minimum of 10% to a maximum of 30% depending on the locality. In the case of the Lakhavali reservoir scheme (cost about 9 crores) recently started where the conditions are analogous to what obtain at Hirakud, the construction allowance is fixed at 20%.

We would, therefore, strongly plead that the facilities as noted below be provided to the staff employed on this project.

(*i*) 20% construction allowance.

(*ii*) Rent free quarters.

(*iii*) Free light, power and water.

(*iv*) Free medical aid.

We are more than convinced that this consideration from the Government will go a long way to secure willing and hard and efficient work.

Another no less important factor is the conditions that have to be created for the workmen. While well laid out colonies with water, light and sanitary conveniences are essential the extent to which the Department can go to create conveniences for them in regard to hutting etc. has to be very carefully considered and suitable conditions laid down for implementation. It should be made obligatory on the part of contractors to deal with their workmen in a more human way than has been the practice hitherto. How far this will force up the rates is a matter for investigation.

It is stated that the rates provided are all based on 1946 schedule. Excesses on these estimates have to be expected as at every stage the conditions of the labour are getting more and more unfavourable. The wages are running high consistent with the prices of food grains etc. and there is a tendency to work less. All these factors create conditions which require very careful, tactful and sympathetic but firm handling.

Conclusion.—The height of the dam is 135 feet. The bed of the river is rocky and good foundation is available right through at small depths, the river flow in the working months is too small for such a great width of 10,000 feet taking the branches together ; all the materials are available close-by. There are no insuperable difficulties of any kind. The execution and satisfactory completion of the scheme depends only upon the building up of an organization to work out the programme. In our judgment, with the drive and energy and vision that has been brought to bear upon the formulation of the unified development scheme of the Mahanadi Valley and the detailed investigation of Hirakud, the first of the reservoirs in such a short period, there is no doubt, whatever, that this reservoir scheme will be successfully brought to fruition bringing plenty and prosperity to the Greater Orissa by increased food production and industrial expansion.

PART III

HYDRO-ELECTRIC

1. Basic Hydraulic Data.

Hydraulic data submitted to us is reproduced below :

Maximum reservoir level	R. L. 625·0
Minimum " "	R. L. 590·0
Maximum tailrace level	R. L. 515·0
Minimum " ,,	R. L. 510·0
Average ,, ,,	R. L. 512·0
Storage capacity of reservoir up to R. L. 625.0	5·98 m.a.ft.
Dead storage capacity up to R. L. 590.0	2·24 ,,
Capacity of Pond No. 1, 5′ draw down	2,900 acre ft.
Length of power channel between Pond No. 1 and Pond No. 2	7,000 ft.
Capacity of Pond No. 2, 4′ draw down	3,072 acre ft
Length of Power channel between Pond No. 2 and Pond No. 3	30,500 ft.
Pond No. 3, capacity for 3′ draw down	11,100 acre ft.
Maximum Pond level at No. 2 P. H.	R. L. 512·0
Minimum Pond level at No. 2 P. H	R. L. 509·0
Normal tailrace level below No. 2 P. H.	R. L. 432·0
Normal flood level below No. 2 P. H.	R. L. 445·0
Water level in Mahanadi below No. 2 P. H.	R. L. 426·6

The above data is shown pictorially at Fig. 1.

2. Choice of year as basis for estimating power potential.

There are different methods by which hydraulic data on the flow of a river can be taken into account for determining the basis for estimating power potential. The two common methods are (1) average year basis, and (2) time percentage basis.

In the average year basis method average flow for any given month is taken for as long a period as the record is available. This flow is then taken as the flow for that month. In this way complete year's record is created, and then this record forms an average year for estimating power potential. By the second method the duration of any particular flow is expressed as percentage of time and a flow duration curve is drawn indicating the flow in any particular month.

Average year basis is accepted for calculating the water available in this case, because this gives figures for flow per month less than the second method, and, therefore, they can be more depended upon to repeat in practice.

3. General description of the Hydraulic system as it affects power generation.

The dam at Hirakud will impound water to the extent of 5·98 m. a. ft. at R. L. 625.0. This storage will serve the purpose of reducing flood peaks, supplying water for irrigation and power after allowing for dead storage, evaporation losses, etc.

The inflow will fluctuate from month to month and also from year to year during the period of dry months, *viz.* November to June. This would be the limiting factor for primary power. The inflow during rainy season is quite in excess of primary power requirements, and therefore, it can only be taken into account for the development of secondary power.

For power purposes, 5·84 m.a. ft. will be available from November to June from storage, and the run of the river.

Water used in No. 1 (Upper) Power House will be reused (after allowing for other requirements) in No. 2 (Lower) Power House by means of a power channel 280′ wide and 16½′ deep connecting three ponds, pond No. 1 forming the tailrace of the Power House No. 1, pond No. 3 forming the forebay of Power House No. 2, and ponds No. 2 occurring in between. The longitudinal section of the power channel is at fig. 10.

Details of levels, capacities, inflow, length of power channel, etc. are given later in this report.

4. Basis of Hydraulic operation of Power House No. 1.

This power house is solely dependent on storage supply for its primary power during the months of November to June, though the storage is augmented to some extent by the run of the river during this period. An average yearfor the run of the river based on 20 years record (1926-46) has been selecte d for determining the primary power.

Use of this power house as base load station, as suggested in the project report, will be very uneconomical. Instead the Power House No. 2 should be operated as a base load station for the reasons explained below.

Advantages of fluctuating daily, weekly, monthly and even eight-monthly (in dry months) load factors, under actual operating conditions, will not be available for storing water during the period of low power demand. The effective head in No. 2 Power House being lower than in No. 1 Power House, the same quantity of water will generate less power in Power House No. 2 than it would do in Power House No. 1.

If system load factor on monthly basis is 70% as per details given later in this report, Power House No. 2 will have to run at 47·8% monthly load factor as against 56% of Power House No. 1, if it is to take the peak-load. This indicates uneconomic use of available water in dry months and also an uneconomic use of the capital outlay in the installed capacity.

5. Hydraulic operation of Power House No. 2.

This Power House is solely dependant on storage capacity between No. 1 and No. 2 Power Houses, and the inflow from Power House No. 1 into the storage.

Therefore, the most economical operation from hydraulic consideration would be, to utilise the available average discharge from No. 1 Power House machines continuously, so that storage is used only as balancing reservoir. There should be no excess in inflow to avoid water going over the spillway at No. 2 Power House unused. Neither there should be any excess consumption of water, as it would deplete the reservoir, affect the water level in power channel, reduce effective head over the turbines, consume more water for the same output etc.

This means that Power House No. 2 should work as base load station, *i.e.* at 100% L. F. all the year round.

This is also in keeping with the general practice that, that power house which generates less power at 100% load factor should work as base load station.

From a consideration of hydraulic operation, this method is, therefore, recommended for operation.

6. Electrical operation of Power Houses Nos. 1 and Nos. 2.

There are three possible methods. They are—

To operate Power House No. 1 as base load station, and Power House No. 2 to take all the fluctuating load.

As pointed out in para. 4, above, this method is uneconomical and, therefore, is not suitable for operation.

Power Houses Nos. 1 and 2 should take their own share of peak or fluctuating load, and no one should operate as base load station.

Hydraulically this is possible with certain advantages, if sufficient pondage is created between No. 1 and No. 2 Power Houses. The economic effect of such increased pondage has not been studied, as electrical operation in parallel of the two power houses will present considerable difficulties, if both the power houses are allowed to take their fluctuating load. This raises the question of "Stability of the machines under synchronous operation in parallel both under steady state and transient conditions."

In view of the above, this method is not recommended.

Power House No. 1 should take all the fluctuating load and Power House No. 2 should operate as base load station. As already discussed above, this method of electrical operation of the two Power Houses is considered economical and suitable for the conditions prevailing.

This is, therefore, recommended for acceptance from consideration of electrical operations as well.

7. Load Factors under operating conditions.

Having decided to operate Power House No. 2 as base load station, and Power House No. 1 to take fluctuating load, the question of load factor for the system under operating conditions needs examination.

No load data has been collected, and, therefore, no load factor can be worked out from the data made available to us.

As we cannot forecast load conditions so much in advance, some typical load curves have been drawn to represent operating daily and weekly load factors as are commonly encountered. These curves are attached herewith as Figs. 2, 3, 4, and 5.

Experience gained on load factors under actual working conditions in the Punjab Hydro-Electric system is that the following load factors are secured in practice without the growth of heavy industries :—

Daily load factors	72%
Weekly ,, ,, ...	63%
Monthly ,, ,, ...	56%

In practice actual load factor may improve with the development of heavy industries, but there can be no adverse effect on the system and the machines will still operate at high

efficiency. This point is further considered in detail while estimating the size of the generating unit.

It may be noted that 56% monthly load factor for Power House No. 1 with 100% load factor for Power House No. 2 would give a system load factor of 70% which represents a very reasonable possibility with the growth of heavy industrial load connected to the system.

8. Fundamental basis of economic operation.

Power Houses Nos. 1 and 2.—Both the power houses are hydraulically connected to each other. Therefore, operation of Power House No. 1 must have a direct bearing on the operation of Power House No. 2. As already stated in para. 6., Power House No. 1 should run as peak load station and Power House No. 2 should operate as base load station. Under this method of operation water released by Power House No. 1 must be consumed by Power House No. 2, within a given limit, without creating any surplus or deficit in the balancing reservoir, over a given period. In this process, steady continuous power generation at 100% load factor in Power House No. 2 must, when added to the output of Power House No. 1, give a constant figure, or at least as close to a constant figure as possible, during the major portion of the year particularly including dry period. Thus alone, we can get maximum primary power from the combined operation of both the power houses. This also means maximum revenue, and, therefore, it is the most economical use of water available foi power generation.

Keeping the above basic principle in view, it is very necessary to re-prepare hydraulic data sheets. In this attempt the following variables have to be taken into account. When any particular power is generated steady for a given period in No. 1 Power House, it draws out a certain quantity of water from the reservoir. This changes reservoir level on the first of next month (month being taken as a unit). In the second month either the power generated could be kept constant, or the water drawn out could be kept constant. If the power generated is constant, then the draw-down from the reservoir keeps on increasing from month to month as effective head keeps on decreasing. If the water drawn is kept constant, power generated keeps on going down, as the effective head keeps on getting less.

Secondly, all the water that comes from Power House No. 1 is not made available or used in Power House No. 2 There is a gravity canal in between, which keeps on taking fluctuating quantity of water for irrigation from month to month, as given in column 18, Table 1. Therefore, the effect of it, on power generation, on Power House No. 2 also keeps on fluctuating. This makes it very difficult to get the total power generated from No. 1 and No. 2 Power Houses constant for major portion of the year, including dry period.

The above will indicate that there are several variables, each having a direct bearing on the total power to be generated, and, therefore, the combined result keeps on changing on every assumption of water drawn from the reservoir each month. It was, therefore, necessary to prepare tables for several different conditions until ultimately best results are obtained. Such a final table is noted below as Table No. 1.

. Examination of Final Data giving re-arranged Hydraulic and Electrical data as per Table 1.

It is obvious that in the preparation ot this table there must be no change in water available from the reservoir, between the period when the tank is full, *i.e.*, 1st of November and the end of June when the tank is at the lowest level. This is taken care of in columns 4 and 5.

Evaporation losses and water required for irrigation purposes, as supplied to us have been kept intact. This is taken care of in columns 7 and 8. Column 9 gives new quantity of water available for power generation from month to month. It is so distributed as to achieve maximum economy in water use and also getting maximum primary power which, in its turn, means maximum revenue.

Columns 10, 11 and 12 only give the results of this revised draw-down from the reservoir. Columns 13 and 14 are utilised to calculate columns 15 and 16. Column 16 gives the anticipated maximum demand, under normal working condition, taken over a period of one month. The reservoir is sufficiently large to store water saved over the week-end and on other holidays in the month, and, therefore, water economy can be calculated on monthly basis.

If this monthly load factor of 56% were to rise in practice, it would only mean that the maximum demand of the power house would be reduced. In that event, generators would be partly loaded at the time of peak demand.

Reference to efficiency curve, Fig. 6, indicates that there is no appreciable difference in efficiency of the unit over a range of 50% load to 85% of full load. Therefore, there will be no uneconomic use of water. Columns 17 and 18 make provision for absorption losses and irrigation requirements as supplied to us.

Column 19 is the result of manipulation of water consumed in Power House No. 1 given in earlier columns. Column 20 is as per basic hydraulic data.

Column 21 has been calculated. Here No. 2 Power House is used as base load station, as explained earlier in this report. Columns 22, 23, 24 and 25 merely record the summated results.

It may be noted here that in Column 24, a specific provision is made for pumping load to the extent of 16,000 KWs. out of primary power. This pumping load is only a rough guess at its best. Therefore, original fluctuating figures need not be followed up rigidly. By keeping 16,000 KWs. steady supply for 12 months, it can be easily sold out as primary supply, if not required for pumping purposes. Any excess requirements can be met by not permitting a certain portion of pumping load during the peak hours, as the load factor, of such a load, is usually only 50% or so.

Any excessive requirements of pumping load in the rainy season as shown in original report can be provided for as secondary power. Therefore, it has been shown as a separate figure in the same column. This load can be met by installing an additional machine, which would serve as a spare machine, during seven months in a year.

Columns 24 and 25 give the total marketable power which is very much in excess of the originally anticipated power, and herein lies the real advantage in following the revised method of utilisation of water and the method of operation of the two power houses.

10. Determination of Generator capacity.

Factors to be taken into account are:—

(*i*) Maximum estimated peak demand should be evenly distributed over a minimum number of units.

(*ii*) Size of each unit should fit in with the practical considerations of size of penstock, weight of unit and its single heaviest component part, transport limitations, operating facilities, etc.

(*iii*) Smaller the number of units to generate the given power the less in general is the overall cost. Usually three units with one spare or six units with two spares should be the very maximum. This should give very satisfactory operating facilities.

Power House No. 1.—A reference to column 16—Table No. 1—would show that average peak output from January to June works to 151,000 KWs. When distributed over three machines, it would give a generator size of 50,000 KWs with a corresponding maximum turbine output, with moveable blade propellor type turbines, would be about 88,000 H.P. This

size goes beyond the limit of recognised satisfactory operation with the critical head **available.** Therefore, this size may be passed over as unsuitable.

The next convenient size is obtained by using four machines instead of **three. This** works out to a generator capacity of 37,750 KWs.

Examining the same data from a different angle, we find that the maximum **peak load** of 184,000 KWs, when divided into five machines in the rainy season, gives a **generator** capacity of 36,800 KWs.

If the average size required for dry and monsoon seasons is taken into account, **the size** of individual unit works out to 37,275 KWs.

Considering all the above and remembering that actual working conditions **have only** been visualised as best as we could, a size of 37,500 KWs appears to be the most **reasonable** choice for the generator capacity.

This size would also be suitable from the point of capital outlay, as the cost **per K.W.** installed is expected to be approximately 20 % less than the cost per K.W. for 25,000 **K.W.** sets.

11. Examination of the suitability of Generator Capacity chosen.

Maximum continuous rating generators giving maximum output of 37,500 KWs. **at best** efficiency with 0·9 P.F. lagging, are recommended above.

When 4 machines are in operation, the power house would take 150,000 KWs. **maximum** demand in monsoon months. When a fifth machine is added, the power house would **be able** to take 187,000 KWs. maximum demand.

Applying the above results to the load condition worked out in Table No. 1, **column 16,** when the power house is called upon to take minimum peak demand in any month, **the** machines would be loaded to the extent of 97% full load. When called upon to take **minimum** peak load of monsoon months, the machines would be loaded up to 96% full load. **In dry** months, if only 4 machines are used, they would not be loaded beyond 101% full load, **and in** the rainy season each machine, while carrying maximum peak-load of any month, **will be** loaded up to 98% full load.

All the above factors when referred to the standard efficiency curve indicate **that the** machines with the size selected would still be able to carry the fluctuating maximum **demand** from month to month at practically the same efficiency as the maximum efficiency **for the** generator. So, from considerations of efficiency the set chosen is quite a suitable one.

Then again 37,500 KW generator rating will correspond with 66,500 H.P. turbine **rating** which size is within the practical limits of successful operation under the critical head **available.**

Therefore, generators of 37,500 KW M.C.R., 0·9 P.F. lagging have been taken **for** further calculations in this report.

Effect of load factor variation.—In the revised Table No. 1, monthly load factor is **taken** as 56% for Power House No. 1. This really means a system load factor of 70% on **monthly** basis when Power House No. 2 is working at 100% load factor. This also indicates that **daily** and weekly load factors of the system could be still higher. This condition has to be **anticipated** with the growth of heavy industries, which are very necessary for the **consumption of** large bulks of power within a reasonable time.

Any variation in actual operation cannot affect water economy, because K.W. **hours** consumed would remain the same for a given load. It will only affect the peak **demand,** generators may be called upon to take for a short period. This means that under **extremely**

low load factors, one more machine may be called upon to help in taking the high peak load, for an hour or two per day, or once in a while. This condition cannot arise until both the power houses are almost fully loaded, and then it would be easy to estimate the necessity of an additional machine, or the use of a spare unit during this short period, as the case may be.

In case the system load factor keeps on rising and goes beyond the estimated 70%, the only effect it will have is, that the generators would be partly loaded at the time of peak load. This part load, (that is percentage of full load) is still a very high percentage, and, therefore, the unit would still be operating with a high efficiency.

So the assumption of operation of No. 1 Power House at 56% monthly L.F. gives almost all the advantages without introducing any disadvantage.

Power House No. 2.—Following the same considerations as are given for Power House No. 1, generator capacity proposed to be installed is 24,000 KWs. Three such sets would be suitable for carrying estimated maximum load as per column 20, Table I, for all the 12 months.

12. Examination of suitability of the Generator Capacity Chosen.

It will be noticed from Col. 21, Table I, that the maximum output of this power house at 100% load factor during 12 months would be 72,000 KW, and that the minimum would be 57,000 KW. for any month. In the former case the machines would be loaded upto cent per cent full load, and in the latter case upto 79·5 % full load.

So from efficiency point of view, the machines would run all the year round at maximum efficiency. This size is well within the maximum limit of turbine output for satisfactory operation at the critical head available at this power house.

Electrical characteristics of generators.

Power House No. 1—

Generator output at M. C. R. with 0·9 lagging Power factor	.. 41,600 kVA.
Normal generator voltage with a variation range of 9,350 to 12,100 volts. ..	.. 11,000 volts
Charging capacity of the generator at Zero P. F. leading at 9,350 volts.. ..	.. 30,300 kVA

Power House No. 2—

Generator output at max. M. C. R. with 0·9 lagging Power factor	.. 26,700 kVA.
Normal generator voltage with a variation range of 9,350 to 12,100 volts ..	.. 11,000 volts.
Charging capacity of the generator at Zero P. F. leading at 9,350 volts ..	.. 21,360 kVA.

13. Selection of Type of Turbine.

There are two types of turbines that can be used, namely, moveable blade propellor type (Kaplan) or Francis type. Before we proceed to work out details of water turbine, it is necessary to decide which of the above two types should be used in Power Houses No. 1 and 2.

On detailed consideration it is found desirable to use moveable blade propellor type turbine, as it will provide the following advantages as compared with the Francis type :—

(*i*) Higher efficiency over a wide variation in head.

(*ii*) Higher specific speed, and therefore, less cost for a generator.

(*iii*) Overall efficiency will be higher under part-load operating conditions. This would give most economical use of water, *i.e.*, more average output with the same quantity of water.

(*iv*) Physical dimensions comparatively smaller.

(*v*) Weight will be comparatively less.

(*vi*) Saving in power house building cost, as the space taken by the machine will be less.

(*vii*) Crane capacity will also be less thereby introducing saving in crane cost, supporting structure etc.

14. Determination of Turbine capacity and its characteristics.

Power House No. 1.—The following data has been calculated on the basis of moveable blade propellor type turbines (Kaplan or feathering propellor type) :—

Generator output	37,500 K. W.
Turbine out-put at best efficiency	52,000 H. P.
Maximum output of turbine	66,500 H. P.
Average head	96 Feet.
Critical (design) head	78 Feet.
Specific speed	110 to 148 R. P. M.
Synchronous speed	111 to 150 R. P. M.
Inlet diameter	17′—9″
Outlet diameter	17′—6″
Distance from centre line of turbine to centre line of runner	6·8 Feet.
Distance from centre line of distributor to bottom of draft tube	49·0 Feet.
Elevation of runner with respect of minimum tailrace level	Minus 10 Feet.
Unit spacing from centre to centre	63·0 Feet.

Power House No. 2—

Generator output	24,000 K. W.
Turbine output at best efficiency	33,000 H. P.
Maximum output of turbine	39,000 H. P.
Average head	74 Feet.
Critical (design) head	65 Feet.
Specific speed	123 to 148 R.P.M.
Synchronous speed	125 to 150 R.P.M.
Inlet diameter	15′—2″
Outlet diameter	15′—2″
Distance from centre line of distributor to centre line of runner	5·5 Feet.
Distance from centre line of distributor to bottom of draft tube	40 Feet.
Elevation of runner with respect to minimum tailrace level	Minus 7 Feet.
Unit spacing from centre to centre	52 Feet.

15. Spare Capacity.

Power House No. 1.—As stated in para. 11, four machines will be in operation for nearly 7 months in a year, and five machines for the remaining period.

If heavy repairs are concentrated in a period when only four machines are required, it should be possible to operate the power house successfully with only one machine as spare, when five machines are in operation. With such an arrangement it should be possible to carry out minor repairs, adjustments and routine maintenance works with one spare machine which could be put back into service within few hours of an emergency.

So, the installed capacity should be 6 units. However, space should be provided for 2 more units, as possible extension for secondary load and additional spare machine, if at all necessary, at any future date.

For the additional 2 units mentioned above it would be enough, if the foundations are built up to the tailrace level. No superstructure need be constructed unless it is required.

Power House No. 2.—As stated in para. 11, three units would be enough for taking full load all the year round, and, therefore, as per standard practice, one additional unit would be required as spare, making the total of four units.

It should be noted that during the period of dry season, water economy is most important to get maximum output and, therefore, maximum revenue. During this period all the water released through Power House No. 1 will have to be continuously used in Power House No. 2. Therefore, when 3 machines are required in Power House No. 2 to take up the developed load, anything going wrong with one of the machines, water will have to be allowed to pass over the spillway at Power House No. 2 unused, unless the fourth machine recommended as spare is also installed and kept ready for service.

Strictly speaking when we have made provision of 75,000 KWs in Power House No. 1 for secondary power covering a period of three months or so, it is very doubtful whether it would be an economic proposition to keep on multiplying sets in Power House No. 2 when water economy is absolutely of no consequence during this period. As such no additional units are likely to be installed in Power House No. 2. However, as an extreme case, foundations up to the minimum water level of the Mahanadi, below Power House No. 2, may be built up for one more unit, without incurring any expenditure on the superstructure, for any unforeseen contingency.

16. Penstock opening in the Dam.

Power House No. 1.—As stated in para. 15, six units will be in operation, and there will be provision for two more units. Therefore, eight penstock openings may be constructed in the dam.

Power House No. 2.—As stated in para. 15, four units will be in operation and provision has been made for the possible fifth, five penstock openings may be constructed.

17. Emergency Spillway arrangement.

In the Lower Power House provision for emergency spillway should be considered.

18. House Service Set.

A small turbo-generator set is always required for running the auxiliaries in the power house and for station supply on all occasions when the main units are out of commission for some time on any account. Therefore, one such set should be provided in Power House No. 1 and one set in Power House No. 2.

19. Effect of Driest Year on Power Generation at Power Houses Nos. 1 & 2.

It has been noticed from the available records that one driest year in 20 years is likely to reduce power generation capacity to the extent of about 25 to 30%. Such a contingency can be met by following the methods suggested later in this note.

However, apart from the adoption of such methods, it is obvious that, if such a driest year were to appear before both the power houses are loaded below 75%, it will have no adverse effect.

If one more hydro power station series is in operation by this time, then again there will be no adverse effect until the second series of power houses is also fully loaded.

Normal possibilities are that when one series of power houses is 50% loaded, it would be time to undertake the construction of second series, and the process is likely to be continued for a very large number of years, and, therefore, there is no occasion to entertain any fear over the condition of developed load during the period of driest year on any one particular project.

Still, if need be, the following methods are suggested for tiding over the difficulty without permanently reducing the normal power potential of the project.

(*i*) If in general the rainy season appears to be very much below normal, and the driest year is feared, then the reservoir will be filled up to a high level, such as R.L. 628·0.

(*ii*) Reservoir could be filled up somewhat earlier than usual.

(*iii*) Control over consumption of water should be brought into effect sufficiently earlier to spread the shortage over a maximum period, thereby reducing its intensity.

(*iv*) Water for irrigation can also be reduced proportionately for one season.

(*v*) Load could be staggered to reduce the peak demand but as demand affects KW hour consumption, proportionate restriction in consumption can be affected without much inconvenience to the public.

(*vi*) Certain types of load, which generally do not form part of the most essential services can be easily stopped, as is usually done during the war years, thereby affecting a substantial saving.

These and some other methods can be safely used without adversely affecting the interest of the consumers for one season in 20 years.

20. Transmission Line.

Purpose of Transmission Line.—(*i*) To transmit power from hydro power station to the centre of market for power.

(*ii*) To transfer power in bulk to load centre specially selected.

(*iii*) To interconnect different power houses for exchange of power for—

(*a*) economic operation under peak-load condition ;

(*b*) emergency conditions.

In designing a transmission line the following factors should be taken into account :

(*i*) Amount of power to be transmitted.

(*ii*) Selection of voltages for Trunk and Branch transmission lines.

(*iii*) Distance of transmission on various routes and branch routes.

(*iv*) Economic design of transmission lines.

(*v*) Determination of size of conductor, conductor spacing, insulator characteristic supporting structures, spans, wind pressures, weather conditions, altitude, etc.

(*vi*) Voltage gradient.

(*vii*) Insulation coordination.

(*viii*) Insulation levels for normal spans, approach spans and railway crossing spans.

(*ix*) Lightning proof protection, keeping in view isoceraunic level for the locality.

(*x*) Protecting devices of various types for—

(*a*) interconnection ;

(*b*) interchange of power between different generating units ;

(*c*) abnormal line faults, etc.

(*xi*) Determination of electrical characteristics of line after taking into account various equipment to be connected therewith.

(*xii*) Examination of synchronous condenser capacity and its location.

(*xiii*) Determination of number and size of earthwire and its protective angle.

In designing Trunk Transmission Lines the possibility of developing a "national grid" to interconnect the major hydro-electric stations likely to be constructed should be kept in view. It is more than likely that transmission at 220 KV will have to be adopted in such a development. It might be in the national interest to provide some additional minor expenditure on selected routes to help such future development which will have many advantages.

Secondly, multiplication of 132 KV lines will not be an economic proposition if the power to be transmitted in any one direction were to require more than two circuits.

Thirdly, possibility of erection of an additional line, parallel to the same route at a later date will involve a large number of practical difficulties when the locality under the lines becomes a developed area with industrial and agricultural activities in its vicinity. This will increase the cost very considerably.

All these and many more details have not been studied at all in the report under review. This forms an extensive study by itself and cannot be undertaken as a part of this report. It is, therefore, recommended that this work may please be taken in hand immediately.

21. Grid Substation.

It is very necessary to determine the number of Grid substations and their approximate localities and distances along and away from the main Trunk Transmission Lines.

These substations will also serve as distributing centres for electrical energy, and their capacities will have to be determined keeping in view the requirements of power of the area concerned within the practical limits of transmission by 11 KV lines.

Each Grid Substation will include very large number of different types of electrical equipment, and their details will have to be worked after collecting the necessary data, from the area commanded by these substations.

It will also be necessary to coordinate insulation gradient and protective devices in all the Grid Substations with respect to each other and with respect to extra high tension transmission lines connecting the same.

Interconnection between the generating stations or parallel feeder or ringmain operation will have a direct bearing on many of the factors to be studied in designing such Grid Substations.

It will be obvious that it is an enormous study involving complicated technical detain and practical considerations requiring high technical knowledge, experience and imagination with broad national outlook. It is recommended that this work may be taken in hand at an early date.

22. Local Distribution.

This part of the work has not been dealt with in the project report. Without this work it will not be possible to carry power to the consumers' premises.

We would only record here that the business of distribution of electricity to consumers is a very profitable business, taking into consideration the investment involved.

The organization for re-sale of electricity will be intimately connected with the social and economic life of the common man, and therefore, would exert considerable influence in making or marring the success of any such undertaking.

This is a matter that needs careful consideration. We are strongly in favour of keeping this business of re-sale of electricity in the hands of Provincial Government, and, if such a view is accepted by Government, expenditure on local distribution work will have to be provided for in the project.

If this work is to be undertaken, detail load survey and the design of each local distribution centre will have to be proceeded with, simultaneously with the other work.

23. Cost.

The cost data in the project report are based on the information collected in 1946. Since then there has been a substantial increase and the costs have been fluctuating so much that it is very difficult to make out a correct estimate without obtaining fresh quotations at competitive rates. It should, however, be noticed that certain economies in units and lay-out have been effected as a result of detailed study. This should help in minimising the otherwise likely excess.

24. Revenue.

This has been given in the Project report based on certain revenue per KW of maximum demand per year. In this connection, the following may be taken into account.

Rate Tariff.—The rate tariff should follow the modern practice namely the two-part tariff—demand charge and energy charge.

Demand charge is necessary, because the supplying authority will have to invest in providing for the necessary generating capacity and transmission line capacity and other equipment suitable to carry maximum demand, if called upon to do so, by the consumer at any moment. Energy charge is necessary, as it has a direct bearing on the benefit derived by the consumption of energy from hour to hour.

Demand charge increases with the demand, while the energy charge rate varies inversely with the consumption. This also provides additional incentive to consume more energy so that the average rate per unit may go down.

One more charge called ' Minimum consumption charge ' is also common. But concession can be made to the public by not levying this charge under certain circumstances, while industrial consumers can be called upon to give a minimum consumption guarantee so that electrical energy is not unnecessarily booked up, without recording reasonable consumption taken over a period of 12 months.

Various types of load will call for different types of tariffs, and this subject again can form basis of a separate detailed report at a later date.

Special Consumers.—Cases of special consumers, taking large bulk of power for specialised national industries, have also to be dealt with separately, and for such consumers it is common to have a separate agreement without any reference to standard bulk supply, tariffs intended for comparatively smaller consumers.

Cases of load for water pumping should also be dealt with separately, particularly, if pumping of water at higher levels by Government organisations is undertaken to provide more land under cultivation for food. However, in determining this rate, various factors have to be taken into account, and giving extremely low lump sum rate does not indicate a scientific approach for calculating revenue. If any subsidy, or indirect benefit, is to be given to any class of people, or for any specific purpose, it should be so given under a distinguishable head such as " Subsidy ", and the idea involved should not be mixed up with the question of uneconomic rate permitted to achieve a particular objective should be clearly recorded, and the loss thereof should be accounted for separately.

Indirect Revenue.—Apart from the direct revenue that is secured by the sale of energy, a large electrical project like this produces substantial indirect income to the public and to the Government.

This income can be classed as Indirect Revenue to Government in various ways because of the prosperity and higher standard of living it brings to the public served by the project.

Secondly, it brings a direct prosperity to landholders, urban and rural, by a substantial appreciation in the value of land derived at the proximity of ample electric supply. A portion of such appreciation in land values, should find its way to Government treasury by the introduction of a new tax such as " betterment tax ".

Even this indirect revenue is known to be sufficient to cover interest and depreciation of any normal hydel project.

The combination of direct and indirect charges is always such that a project like this cannot be an uneconomical proposition, if economic justification is the only criterion in developing our national resources.

In brief, it would be fair to assume that no project of such a nature can normally be an uneconomic proposition and therefore, implementation of the project should definitely be proceeded with firmness and speed to achieve some lasting benefit to the public at large.

25. Programme of Power Development.

Programme of development of power largely depends on the development of load for both the power houses. For want of any load data no definite recommendation can be made.

(*i*) It would be desirable to begin with two units in Power House No. 2, as the construction of the civil works and installation of the machines in Power House No. 2, could be easily done in advance, by a year or two, than Power House No. 1. This will have some obvious advantages in development of load, training of personnel, etc.

(*ii*) Further development of power should be taken up in Power House No. 1 by installing 2 units there.

(*iii*) Still further programme should be made up only after the possibilities of load can be visualised.

(*iv*) Initial tender for power house machinery may be issued for Power House No. 2 at as early a date as possible, because the deliveries for heavy machinery in these days are abnormally long, i.e. ranging from 3 to 4 years.

(*v*) Economical considerations demand that, in the link between power generation and its consumption, there should be nothing missing that would hamper the continuous flow of power generated to the consumer's premises. This means that the necessary Trunk and Branch Transmission Lines, Grid Substations, local distribution lines and substations should be completed with a definite programme coordinated with the development of power generation. It is, therefore, necessary to start work on various branches which would go to make up a complete show simultaneously, or with such time difference that the completion of such works would synchronize with each other, and thus protect the investment from lying idle, because of non-completion of any of the links involved. This also goes a long way in winning the goodwill of the public by satisfying their psychological reaction. It must, therefore, be attempted with thought and care from the very beginning.

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TABLE No. I

WORKING TABLES FOR HIRAKUD RESERVOIR

(Average Inflow 1938-39)

Year. 1	Month. 2	Reservoir level at beginning of the month. R.L. 3	Capacity of reservoir, at the beginning of the month. M. A. ft. 4	Inflow during the month. M.A. ft. 5	Total quantity available. M.A.ft. 6	Evaporation losses M.A. feet. 7	Quantity required for irrigation M.A. ft. 8	Quantity available for power M.A. ft. 9	Total draw-off from reservoir M.A. ft. 10 (7+8+9)	Net capacity at the end of the month M.A. ft. 11 (6—10)	Reservoir level at the end of the month R.L. 12	Discharge available for power generation Cusecs. 13
1938 ..	November ..	625	5·98	1·01	6·99	0·04	0·37	0·74	1·15	5·84	624	12,400
	December ..	624	5·84	0·57	6·41	0·03	0·15	0·68	0·86	5·55	622	10,900
1939 ..	January ..	622	5·55	0·45	6·00	0·04	0·15	0·68	0·87	5·13	619	11,050
	February ..	619	5·13	0·35	5·48	0·03	0·13	0·63	0·79	4·69	615	11,350
	March ..	615	4·69	0·33	5·02	0·05	0·15	0·73	0·93	4·09	610	11,850
	April ..	610	4·09	0·23	4·32	0·05	0·10	0·74	0·89	3·43	604	12,250
	May ..	604	3·43	0·10	3·53	0·07	0·10	0·80	0·97	2·56	594	13,000
	June ..	594	2·56	0·73	3·29	0·05	0·15	0·84	1·04	2·25	590	14,000
	July ..	590	2·25	10·93	13·17	0·06	0·44	1·02	1·52	3·08	600	16,400
	August ..	600	3·08	18·02	21·10	0·06	0·33	0·97	1·36	3·08	600	15,600
	September ..	600	3·08	20·66	23·74	0·07	0·43	0·97	1·47	3·24	602	15,700
	October ..	602	3·24	4·09	7·33	0·05	0·44	0·86	1·35	5·98	625	13,900

Year.	Month.	Head at first fall ft. 14	Power generated at first fall at 100% L.F.K.W. in thousands. 15	Power generated at first fall at 56% monthly load factor K.W. in thousands. 16	Absorption losses in power channel. Cusecs 17	Irrigation requirements in power channel. Cusecs 18	Net quantity available at second fall Cusecs. 19	Head at second fall ft. 20	Power generated at second fall at 100% load factor K.W. in thousands. 21	Total power generated at 100% load factor K.W. in thousands. 22 (15+21)	Total power generated with P.H.I. taking the peaks at 56% M.L.F. K.W. in thousands. 23 (16+21)	Power required for pumping K.W. in thousands. 24	Net primary power available for marketing K.W. in thousands. 25
1938..	November ..	112	103	184	124	1,456	10,841	75	60	163	244	16+26	202
	December ..	111	89·5	160	109	552	10,239	75	57	146·5	217	16	201
1939..	January ..	108	88	157	110	560	10,380	78	60	148	217	16	201
	February ..	104	87·5	156	113	560	10,677	78	62	149·5	218	16	202
	March ..	99	86·5	154	118	560	11,172	78	64	150·5	218	16	202
	April ..	93	84	150	122	392	11,736	78	68	152	218	16	202
	May ..	85	82	146	130	392	12,478	78	72	154	218	16	202
	June ..	79	82	146	140	591	13,269 12,478	78	72	154	218	16	202
	July ..	83	101	180	164	1,676	14,560	65	70	171	250	16+32	202
	August ..	88	101·5	181	156	1,231	14,213	65	69	170·5	250	16+32	202
	September ..	88	102	182	156	1,676	13,868	65	67	169	249	16+32	201
	October ..	101	103	184	139	1,676	12,085	75	66	169	250	16+32	202

NOTE.—With 56% monthly load factor in No. 1 Power House operating in parallel with 100% load factor on No. 2 Power House system load factor works out to 70% which is a very reasonable possibility with heavy industrial load connected to the system.

ENCLOSURE 1.

NOTE BY SHRI A. N. KHOSLA, CONSULTING ENGINEER WITH THE GOVERNMENT OF INDIA, FOR THE HIRAKUD DAM ADVISORY COMMITTEE DATED THE 12th MAY, 1948.

Reservoir capacities.

Since writing the 1947 project report, contoured 4-"1 mile maps of the reservoir area have become available and the capacities reworked. Appendix I gives the new capacity figures for different heights.

Silting of reservoir and silt reserve.

In the project report provision has been made for an annual silt yield of 24,000 acre ft. from a catchment area of 32,200 sq. miles above the Hirakud Dam and of this 50% is assumed to be depositing each year in the reservoir and 50% escaped below the dam.

The total silt yield of this catchment during 1947 (January to December) was 33,235 acre feet (Appendix II) and the runoff 39·18 million acre feet. The mean annual runoff of the Mahanadi at Hirakud is 50.00 m.a. ft. (page 15 of report). The silt yield for a mean year, on the assumption that the mean silt charge of a catchment is generally carried in a year of mean runoff, the silt yield for the latter year would be $\frac{33,235 \times 50 \cdot 00}{39 \cdot 18} = 42,500$ acre ft. If 50% of this is retained annually in the reservoir, the silt reserve required so that the live storage is not impaired for at least 100 years, will be 2·125 m.a.ft. It is accordingly proposed to fix the dead pond level at R. L. 590·00, capacity 2·24 m.a.ft. instead of 580·00 (capacity 1·57 m.a.ft.) assumed in the June 1947 project.

Deep set sluices.

The silt charges of 1947 consisted of

		m. a. ft.	
Fine silt	.. .. ..	25,131	75·67%
Medium silt	.. .. ..	4,383	13·19%
Coarse silt	.. .. ..	3,721	11·14%
Total silt	..	33,235	

The large proportion of fines *i.e.*, 75·67%, in the total silt charge is fortunate both from the point of view of silt exclusion and of providing manure for fields. But to make sure that at least 50% of the total silt does escape below the dam, it will be desirable to provide for the entire spillway capacity through deep set sluices (as in the case of Aswan Dam in Egypt) instead of over the crest of the dam. This arrangement will enable the diversion of the river to be done through these sluices and thus facilitate and expedite construction. Also, it will save the cost of a road bridge which would be necessary in the case of spillway over crest of dam.

Maximum floods and flood reserve.

In the project report a maximum flood of 9,42,000 cusecs has been assumed at Hirakud. This was deduced from the 1,570,000 cusecs maximum flood at Naraj in the ratio of 32,200 : 51,000, the respective catchment areas in sq. miles above Hirakud and Naraj. On later consideration and particularly in view of the abnormal floods of 1947 in the Punjab rivers, which far exceeded all previous records, it is proposed to take the maximum flood at Hirakud as $\left(\frac{32,200}{51,000}\right)^{\frac{3}{4}} \times 1\ 70,000 = 1,110,00$ cusecs based on the empirical formula $Q = CM^{\frac{3}{4}}$ where-Q is maximum flood discharge in cusecs, C a constant and M the catchment area in square miles.

From the graph of flood freque ,ies at Naraj, figures for maximum flood discharge at Naraj have been derived and those at Hirakud computed on the basis of the above formula, as follows :

	At Naraj (Cusecs)	At Hirakud (Cusecs)	Flood inflow between Hirakud and Naraj (Cusecs)
10,000 year flood	1,700,000	1,205,000	495,000
1,000 year flood	1,650,000	1,170,000	480,000
500 year flood	1,640,000	1,160,000	480,000
250 year flood	1,630,000	1,155,000	475,000
100 year flood	1,570,000	1,110,000	460,000
50 year flood	1,520,000	1,075,000	445,000

Working on the basis of a 100-year, 1,000-year and 10,000-year flood, the flood reserves at Hirakud and the corresponding gauge heights at Naraj work out as follows :—

Gauge at Naraj.	Total Discharge at Naraj	Inflow between Hirakud & Naraj	Regulated flood discharge at Hirakud	Regulated flood Reserve	Dead Pond Capacity	Total Capacity	Reservoir level
	Cusecs	Cusecs	Cusecs	M. A. FT.	M. A. FT.	M. A. FT.	
				100-year flood			
90·35	1,260,000	460,000	800,000	3·41	2·24	5·65	622·8
90·2	1,240,000	350,000	780,000	3·74	2·24	5·98	625·0
90·1	1,215,000	460,000	765,000	4·04	2·24	6·28	627·0
90·0	1,210,000	460,000	750,000	4·39	2·24	6·63	629·26
89·8	1,200,000	460,000	740,000	4·51	2·24	6·75	630·0
				1,000-year flood			
90·3	1,250,000	480,000	770,000	4·52	2·24	6·76	630·0
				10,000-year flood			
90·8	1,325,000	495,000	830,000	4·49	2·24	6·73	630·0

The safe flood gauge at Naraj has been accepted as 90·10 (vide page 48 of June 1947 Project Report). From the above table this gauge can be definitely secured in the case of a 100-year flood. For a 1,000-year flood regulation can be done so as not to exceed a 90·3 gauge at Naraj. Some damage will result but it will not be very material. For a 10,000 year flood, however, the regulated gauge at Naraj will be 90·8 inspite of the fact that the pond will have been raised to the ultimate level of 630·00. Substantial damage will occur in this case but it will have to be faced once in 10,000 years.

APPENDIX I.

Hirakud Reservoir Capacity and Area.

Revised May 1948

Reservoir Level	Reservoir Area in acres	Reservoir Capacity M. A. Ft.	Reservoir Levels	Reservoir Area in Acres	Reservoir Capaci M. A. Ft.
630		6·75	604	98,077	3·47
629		6·59	603	96,892	3·37
628		6·43	602	95,707	3·27
627		6·27	601	94,522	3·17
626		6·12	600	93,337	3·08
625	1,50,380	5·98	599	91,461	2·99
624	1,47,197	5·83	598	89,583	2·90
623	1,44,013	5·68	597	87,705	2·81
622	1,40,830	5·54	596	85,828	2·72
621	1,37,647	5·40	595	83,950	2·64
620	1,34,464	5·26	594	82,071	2·56
619	1,30,931	5·13	593	81,094	2·48
618	1,27,399	5·00	592	78,316	2·40
617	1,23,866	4·87	591	76,438	2·32
616	1,20,333	4·75	590	74,560	2·24
615	1,16,800	4·63	589	72,972	2·16
614	1,34,478	4·51	588	71,335	2·08
613	1,11,157	4·40	587	69,798	2·01
612	1,09,835	4·29	586	68,210	1·94
611	1,07,514	4·18	585	66,624	1·87
610	1,05,192	4·07	584	65,037	1·81
609	1,04,003	3·97	583	63,449	1·75
608	1,02,818	3·87	582	61,862	1·69
607	1,01,653	3·77	581	60,275	1·63
606	1,00,448	3·67	580	58,688	1·57
605	99,263	3·57			

APPENDIX II.

Silt Charge of the Mahanadi above Sambalpur (1947).

Month	Total discharge (cusecs)	Cumulative discharge (cusecs)	Sediment load for the whole month in acre ft.			Total	Cumulative
			Coarse	Medium	Fine		
January	1,06,020	..	*Nil*	*Nil*	49·26	49·26	..
February	1,06,102	2,12,122	,,	0·08	33·91	33·99	83·25
March	78,475	2,90,597	,,	*Nil*	19·26	19·25	102·51
April	40,241	3,30,838	,,	,,	6·16	6·16	108·67
May	15,385	3,46,223	,,	,,	0·75	0·75	109·42
June	34,674	3,80,897	0·09	,,	9·89	0·98	119·40
July	71,35,447	75,16,334	1,682·62	1,631·52	11,183·44	14,497·58	14,616·98
August	42,09,832	1,17,26,166	1,237·00	1,803·24	6,900·19	9,940·43	24,557·41
September ..	61,29,403	1,78,55,569	773·92	924·89	6,295·70	7,994·51	32,551·92
October	13,84,535	1,92,40,104	27·69	23·42	612·93	664·03	33,215·95
November	2,22,951	1,94,63,055	*Nil*	0·21	13·66	13·87	33,229·82
December	1,26,781	1,95,89,836	*Nil*	0·05	5·48	5·53	33,235·35
			3,721·23	4,383·50	25,130·63		

ENCLOSURE 2

NOTE ON THE SUSPENDED SEDIMENT LOAD OF THE MAHANADI RIVER AT SAMBALPUR DURING 1947

By

Dr. R. C. Hoon,. M. Sc., Ph.D., Officer on Special Duty Central Water-Power, Irrigation and Navigation Commission.

Introductory.

In order to assess the sediment load of the Mahanadi river, water samples were collected daily at ·6 depth at a number of points in the cross section of that river at Sambalpur site during 1947. The sediments carried in suspension in those water samples were separated, graded into three categories ; i.e., coarse (above ·2 mm), medium (·2 mm to ·075 mm) and fine (below ·075 mm) and then separately estimated every day. The observations, made below, are based on the figures of daily discharge and the analytical data of the sediment load.

Suspended Sediment Load.

Fig. 1 shows the daily discharge curve of the Mahanadi river for the year 1947.

The daily loads of the coarse, medium and fine sediments and their total and cumulative values in the river water (expressed in acre ft.) and discharge (in cusecs) for each of the twelve months are tabulated in/tables 1 to 12 (Not printed.) Approximate values of discharge and sediment load for a few non-working days during the year had been interpolated from the corresponding results of the preceding and following working days and, wherever obtained, had been indicated in those tables within brackets.

Table 13 below gives a summary of the results tabulated in tables 1 to 12 for the complete year :

Month.	Total discharge (cusecs).	Cumulative discharge (cusecs).	Sediment Load for the whole month in acre ft.			T ot umulative.	
			Coarse.	Medium.	Fine.		
1	2	3	4	5	6	7	8
January	1,06,020	..	*Nil.*	*Nil.*	49·26	49·26	..
February	1,06,102	2,12,122	*Nil.*	0·08	33·91	33·99	83·25
March	78,475	2,90,597	*Nil.*	*Nil.*	19·26	19·26	102·51
April	40,241	3,30,838	*Nil.*	*Nil.*	6·16	6·16	108·67
May	15,385	3,46,223	*Nil.*	*Nil.*	0·75	0·75	109·42
June	34,674	3,80,897	0·09	*Nil.*	9·89	9·98	119·40
July	71,35,447	75,16,334	1,682·62	1,631·52	11,183·44	14,497·58	14,616·98
August	42.09,832	1,17,26,166	1,237·00	1,803·24	6,900·19	9,940·43	24,557·41
September	61,29,403	1,78,55,569	773·92	924·89	6,295·70	7,994·51	32,551·92
October	13,84,535	1,92,40,104	27·69	23·42	612·93	664·03	33,215·95
November	2,22,951	1,94,63,055	*Nil.*	0·21	13·66	13·87	33,229·82
December	1,26,781	1,95,89,836	*Nil.*	0·05	5·48	5·53	33,235·35
			3,721·23	4,383·50	25,130·63		

Fig. 2 illustrates diagramatically the progressive cumulative figures of discharge and sediment loads for each month of the year. Likewise, variations in total discharge and loads of the various categories of sediment carried by the river water for each month are plotted in fig. 3.

An approximate cumulative discharge of 1,95,89,836 cusecs (about 39,179,672 acre ft. run-off and a cumulative sediment load of about 33,235 acre ft. had been recorded during the year 1947.

Sediment Load in Relation with River Water.

The general feature of the sediment load in the Mahanadi river has been that with an increase in the discharge due to occasional freshet or flood, there occurred an increase in the suspended load of sediment of each category. It was considered of interest to study the variation of the sediment load at various discharge figures. Therefore, the values of (*i*) total sediment load, (*ii*) coarse and medium sediment and (*iii*) fine sediment have been diagramatically plotted against varying discharge figures in figs. 4 and 4(*a*), 5 and (5*a*) and 6 and (6*a*). For ease in plotting the sediment load carried by river discharges upto and below 100 thousands cusecs and those for discharges above 100 thousands cusecs have been plotted separately figs. 4, 5 and 6 represent the former and fig. 4(*a*), 5(*a*) and 6(*a*) the latter.

सत्यमेव जयते

FIG. 1

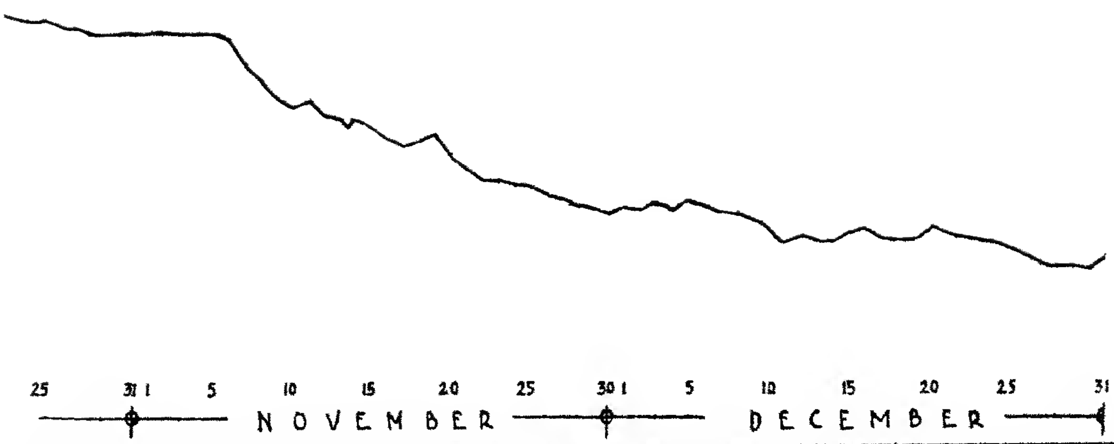
FIG: 1

MAHANADI RIVER

DAILY DISCHARGE CURVE

FOR THE YEAR

—1947—



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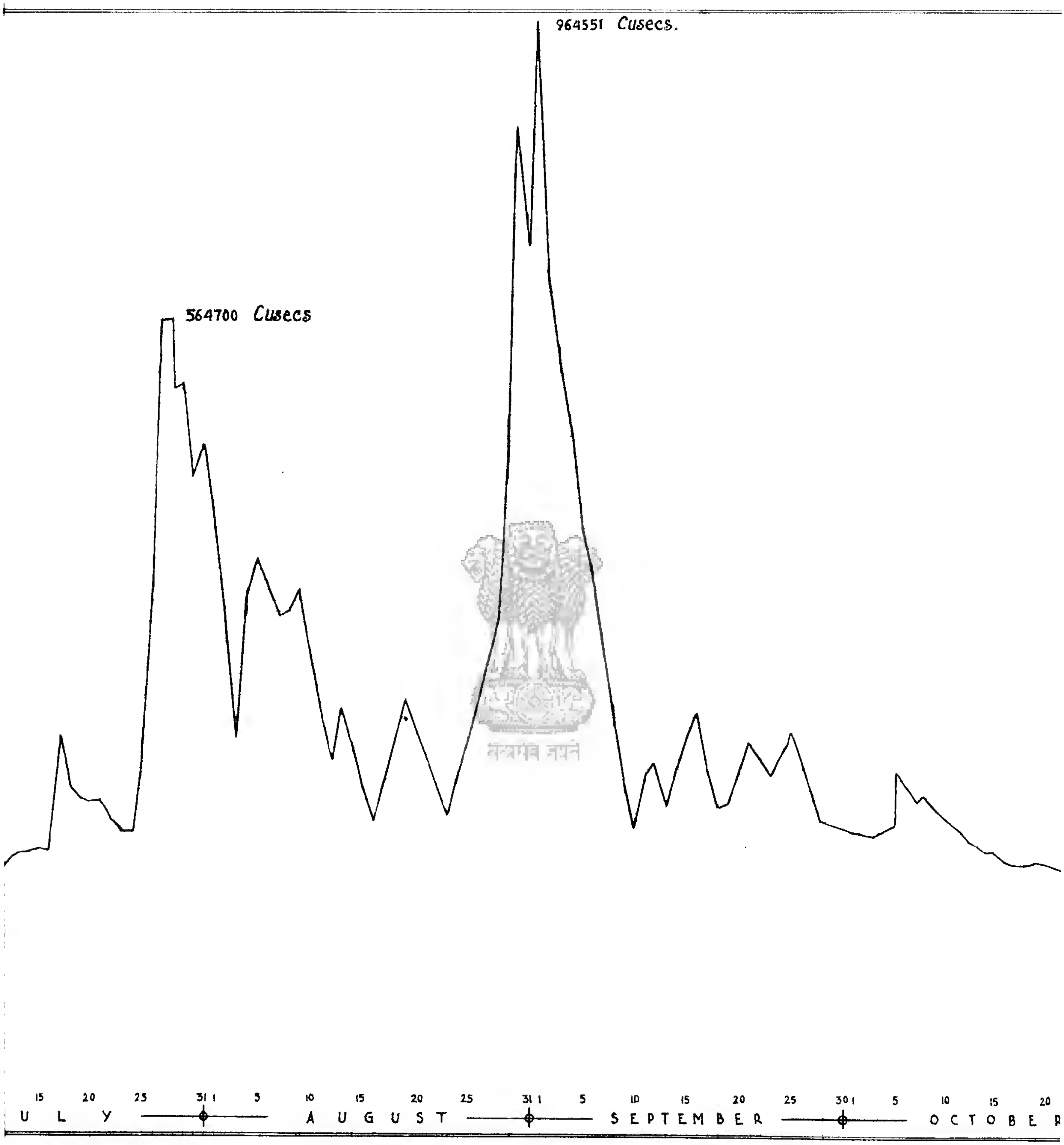
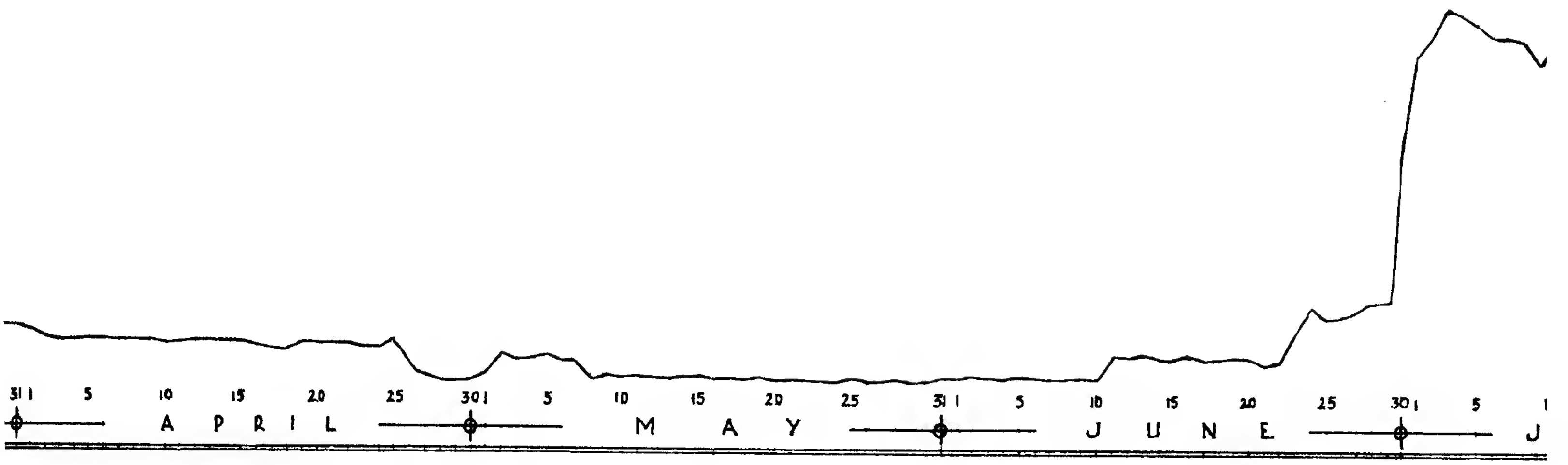
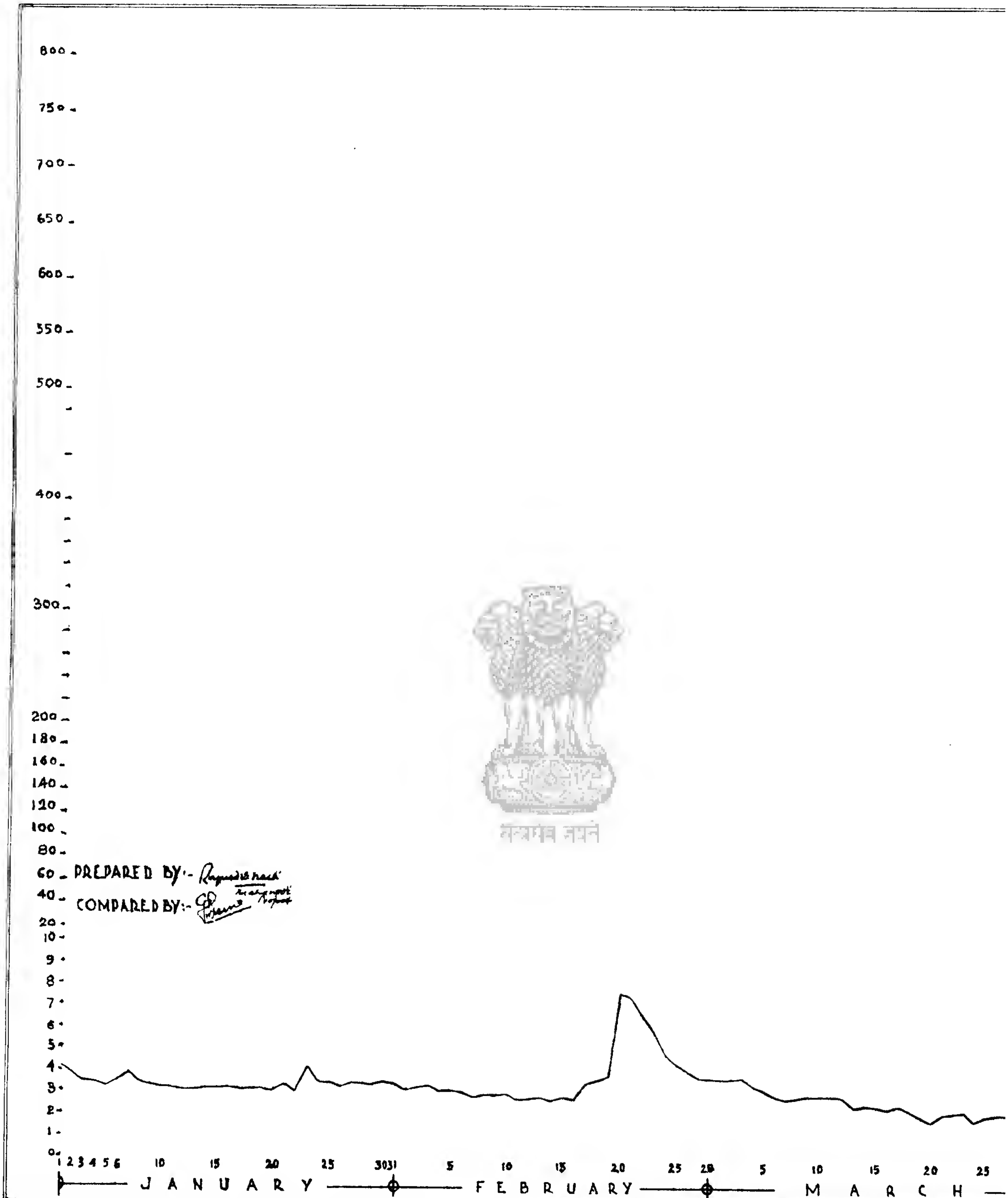

964551 Cusecs.
564700 Cusecs
15 20 25 31 1 5 10 15 20 25 31 1 5 10 15 20 25 30 1 5 10 15 20
U L Y
A U G U S T
S E P T E M B E R
O C T O B E R


31 1
5
10
15
20
25
30 1
5
10
15
20
25
31 1
5
10
15
20
25
30 1
5
1
APRIL
MAY
JUNE
J



Reg. No. 2822 HE'48-

36b

FIG. 2.

DIAGRAM SHOWING CUMULATIVE DISCHARGE AND SUSP ED SEDIMENT LOAD OF THE MAHANADI RIVER DURING [illegible]

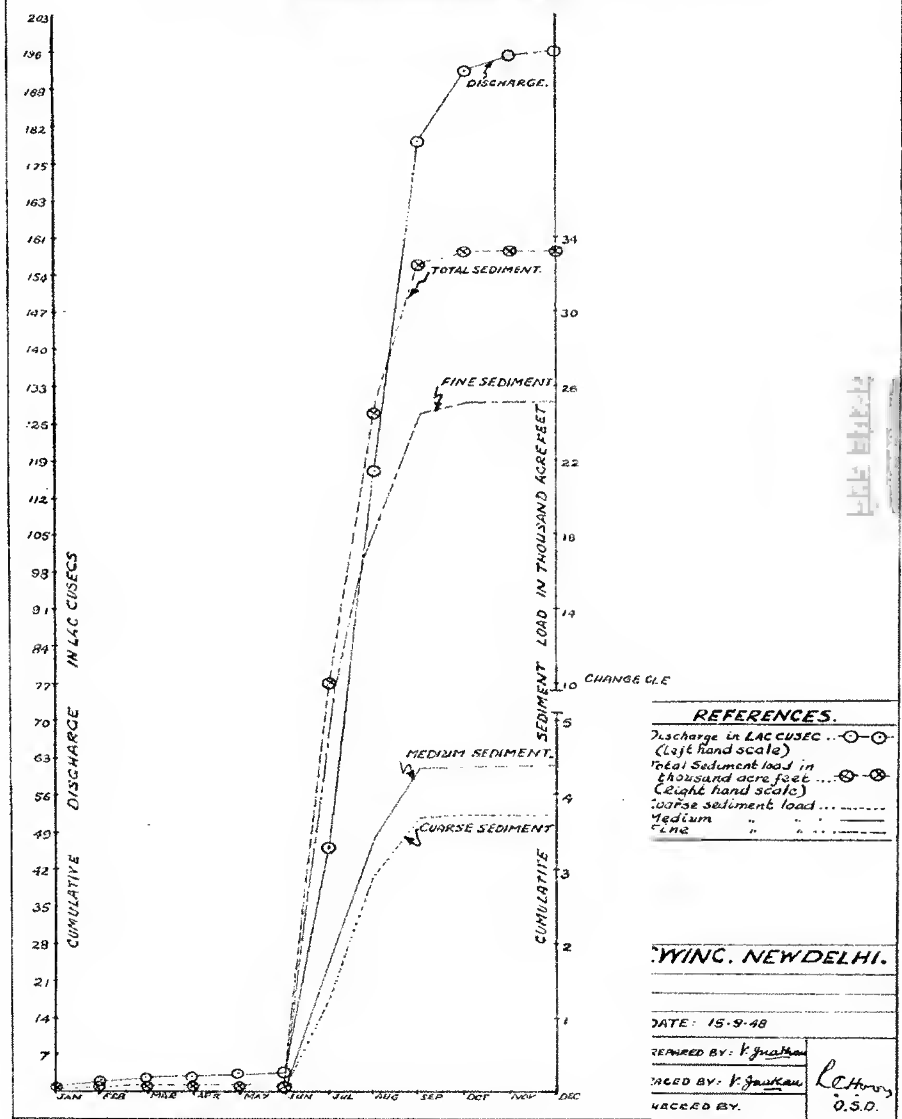


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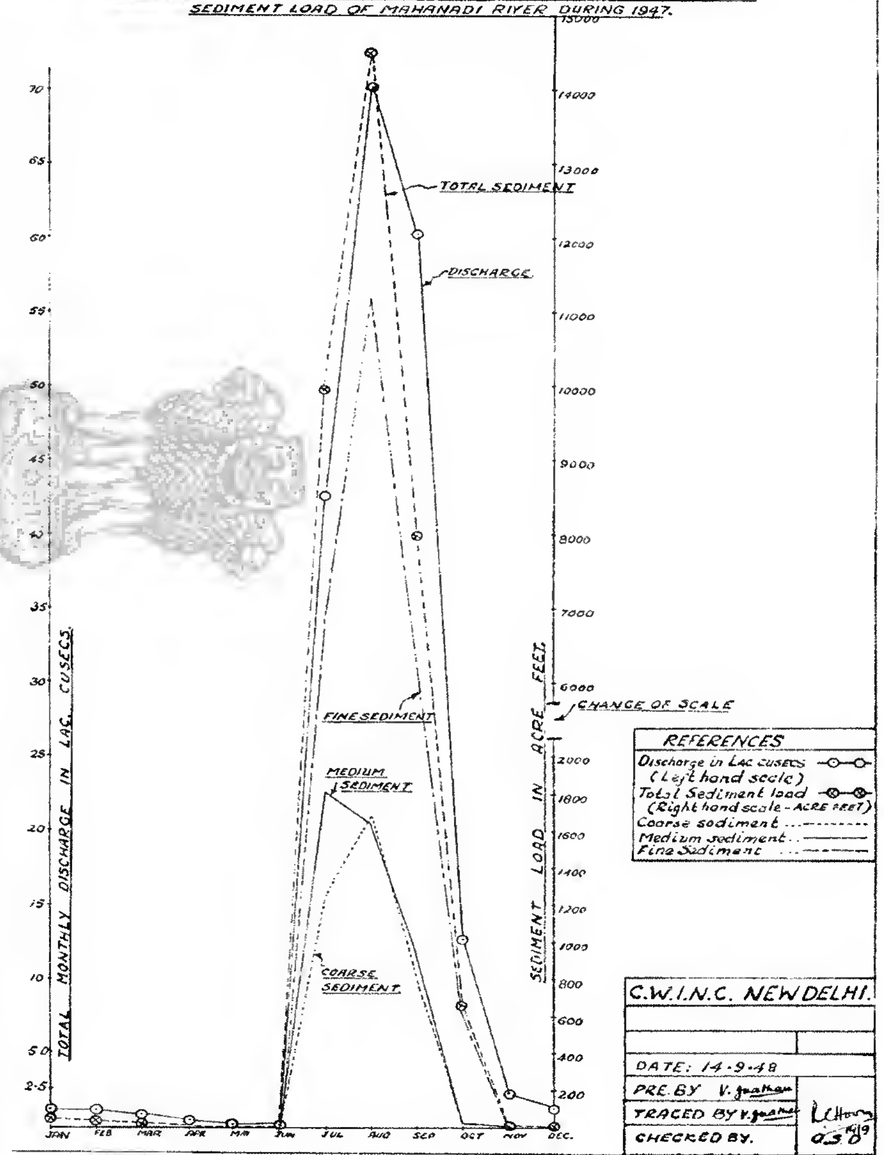
FIG. 3.

DIAGRAM SHOWING THE TOTAL MONTHLY DISCHARGE & SUSPENDED SEDIMENT LOAD OF MAHANADI RIVER DURING 1947.



Reg. No. 2575 X D. O. (C) '48-1003-'49.

Printed at the Survey of India Offices (P. Z. O.).

Cancelled

FIG 2 M-22

DIAGRAM SHOWING CUMULATIVE DISCHARGE AND SUSPENDED SEDIMENT LOAD OF THE MAHANADI RIVER DURING 1947.

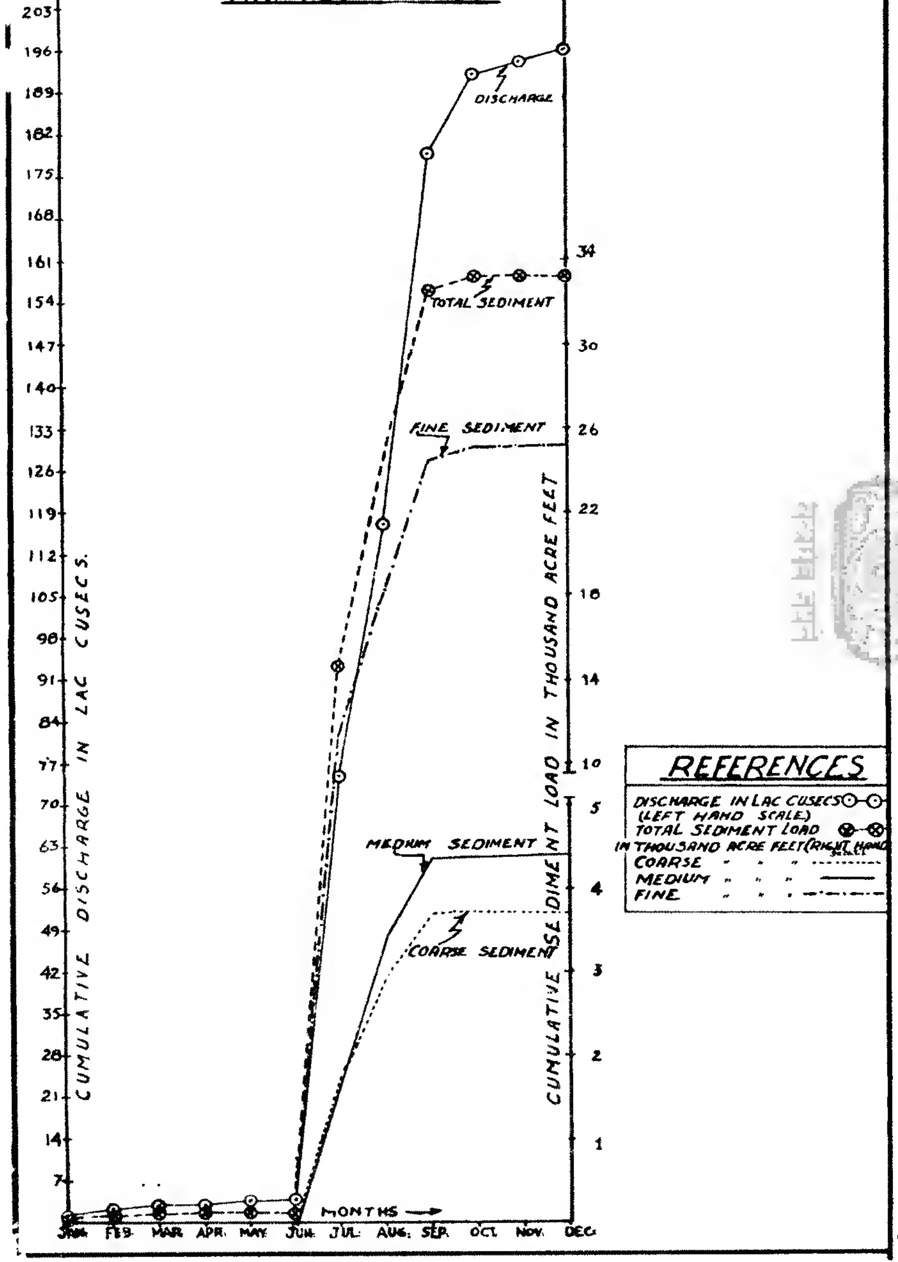
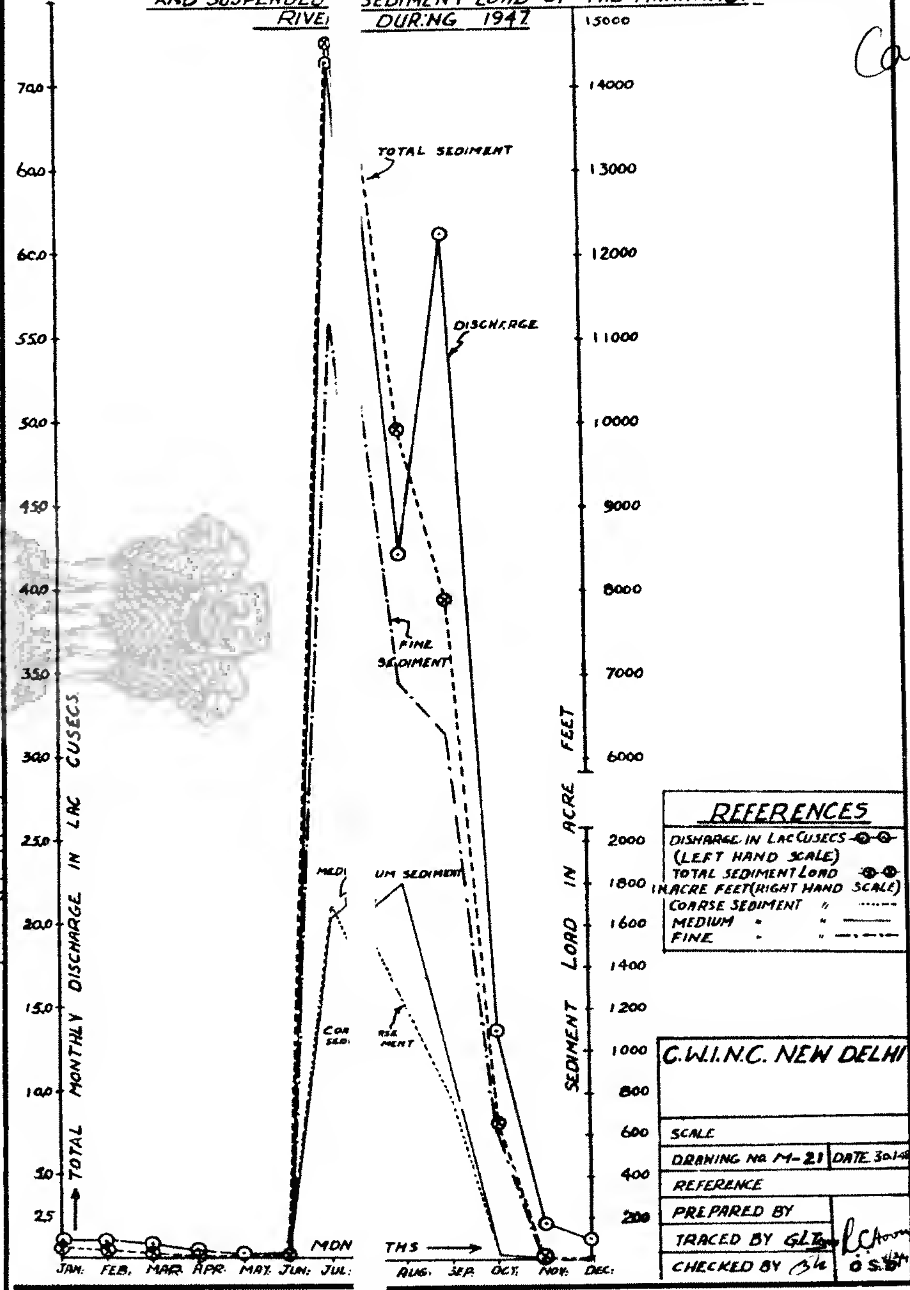


FIG 3 M-21

DIAGRAM SHOWING THE TOTAL MONTHLY DISCHARGE AND SUSPENDED SEDIMENT LOAD OF THE MAHANADI RIVER DURING 1947



C.W.I.N.C. NEW DELHI

SCALE	
DRAWING No. M-21	DATE 30.1.48
REFERENCE	
PREPARED BY	
TRACED BY G.L.T.	
CHECKED BY	

No. 2822 H E '48
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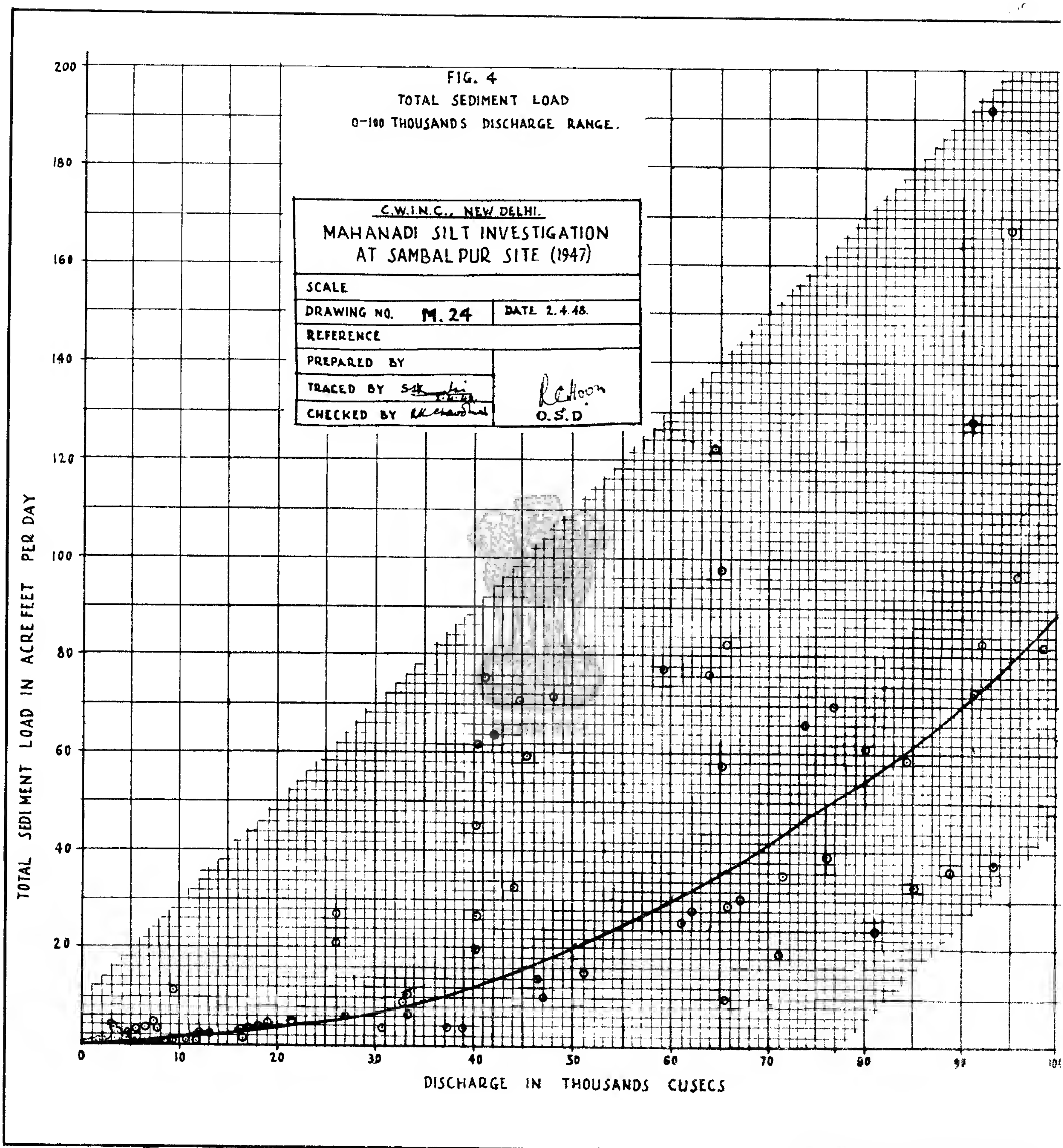
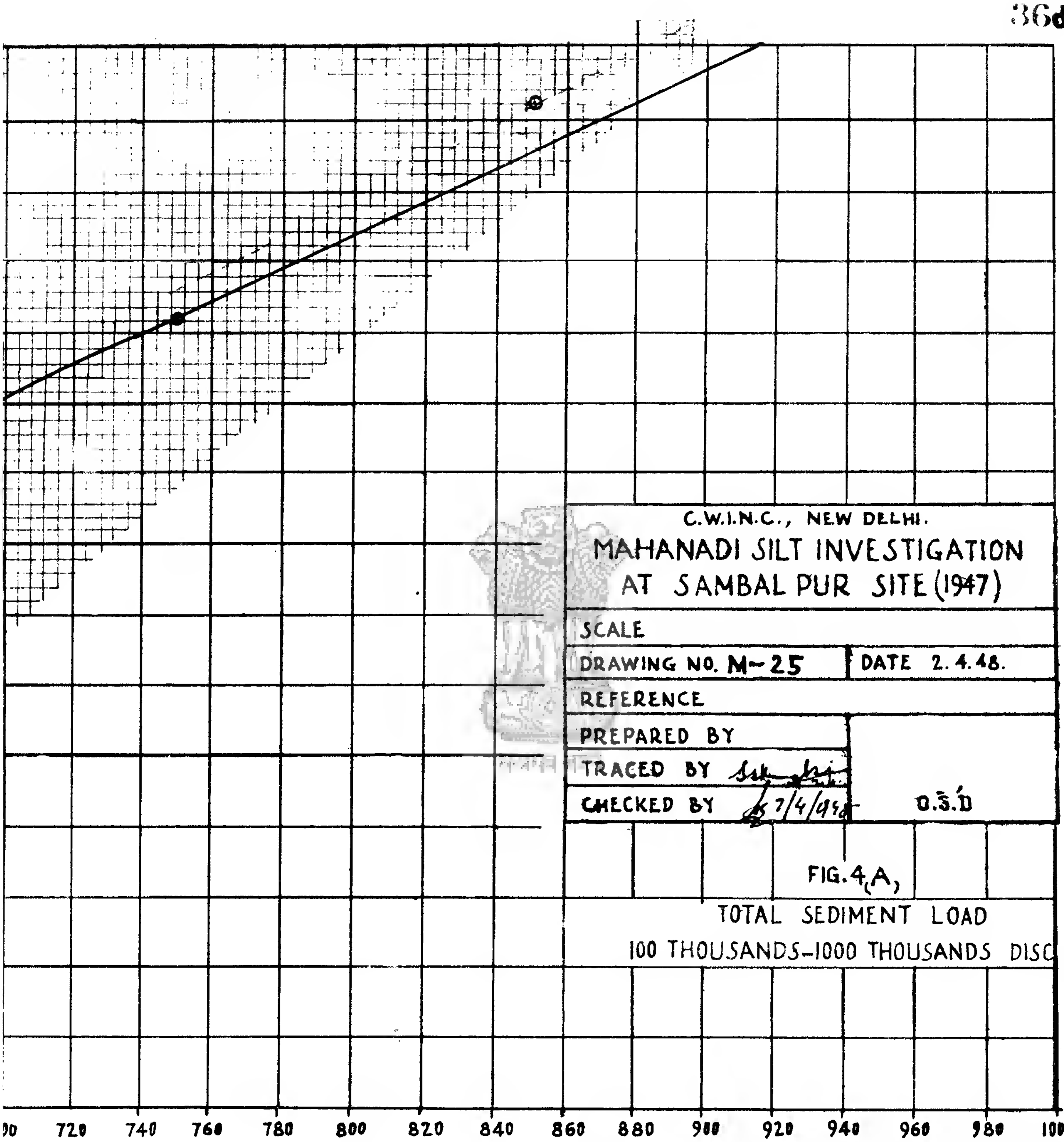


FIG. 4
TOTAL SEDIMENT LOAD
0-100 THOUSANDS DISCHARGE RANGE.
C.W.I.N.C., NEW DELHI.
MAHANADI SILT INVESTIGATION
AT SAMBALPUR SITE (1947)
SCALE
DRAWING NO. M.24
DATE 2.4.48.
REFERENCE
PREPARED BY
TRACED BY
CHECKED BY
O.S.D
TOTAL SEDIMENT LOAD IN ACRE FEET PER DAY
DISCHARGE IN THOUSANDS CUSECS
0
10
20
30
40
50
60
70
80
90
100
120
140
160
180
200



C.W.I.N.C., NEW DELHI.

MAHANADI SILT INVESTIGATION AT SAMBAL PUR SITE (1947)

SCALE	
DRAWING NO. M-25	DATE 2.4.48.
REFERENCE	
PREPARED BY	
TRACED BY	
CHECKED BY 7/4/48	O.S.D

FIG. 4(A)

TOTAL SEDIMENT LOAD
100 THOUSANDS-1000 THOUSANDS DISC RAN

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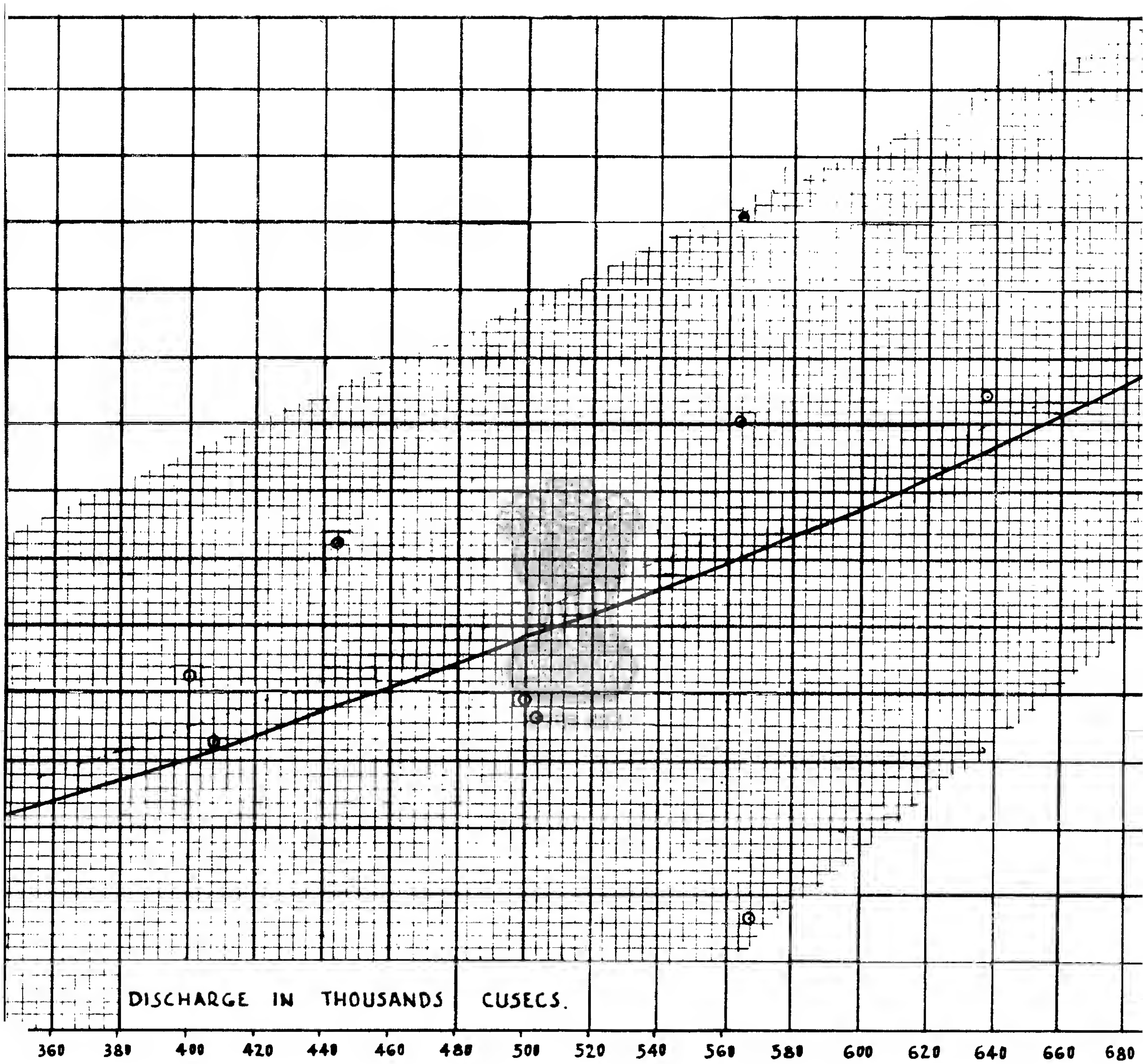
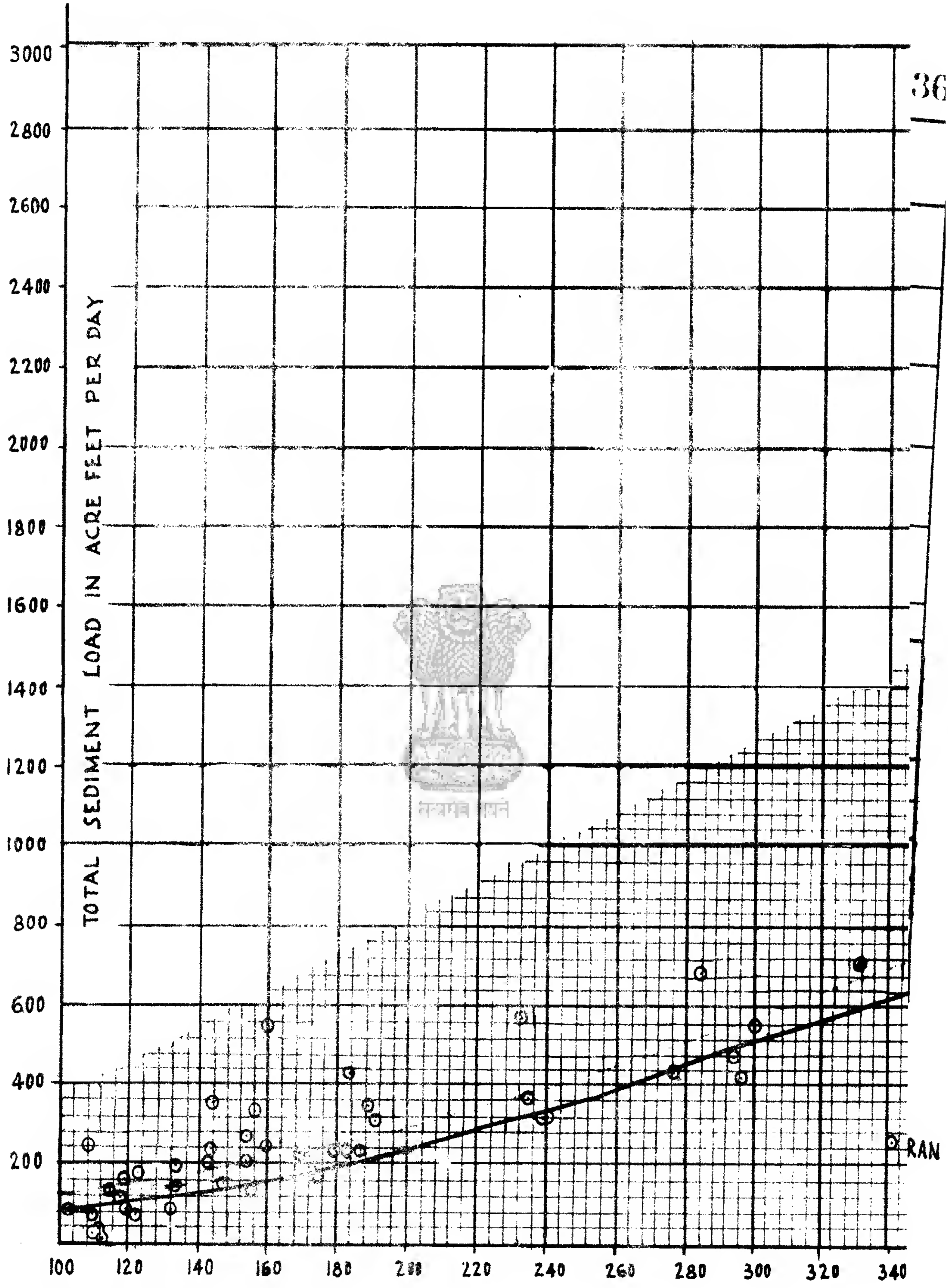


DISCHARGE IN THOUSANDS CUSECS.
360
380
400
420
440
460
480
500
520
540
560
580
600
620
640
660
680



Reg. No. 2822 HE'48-

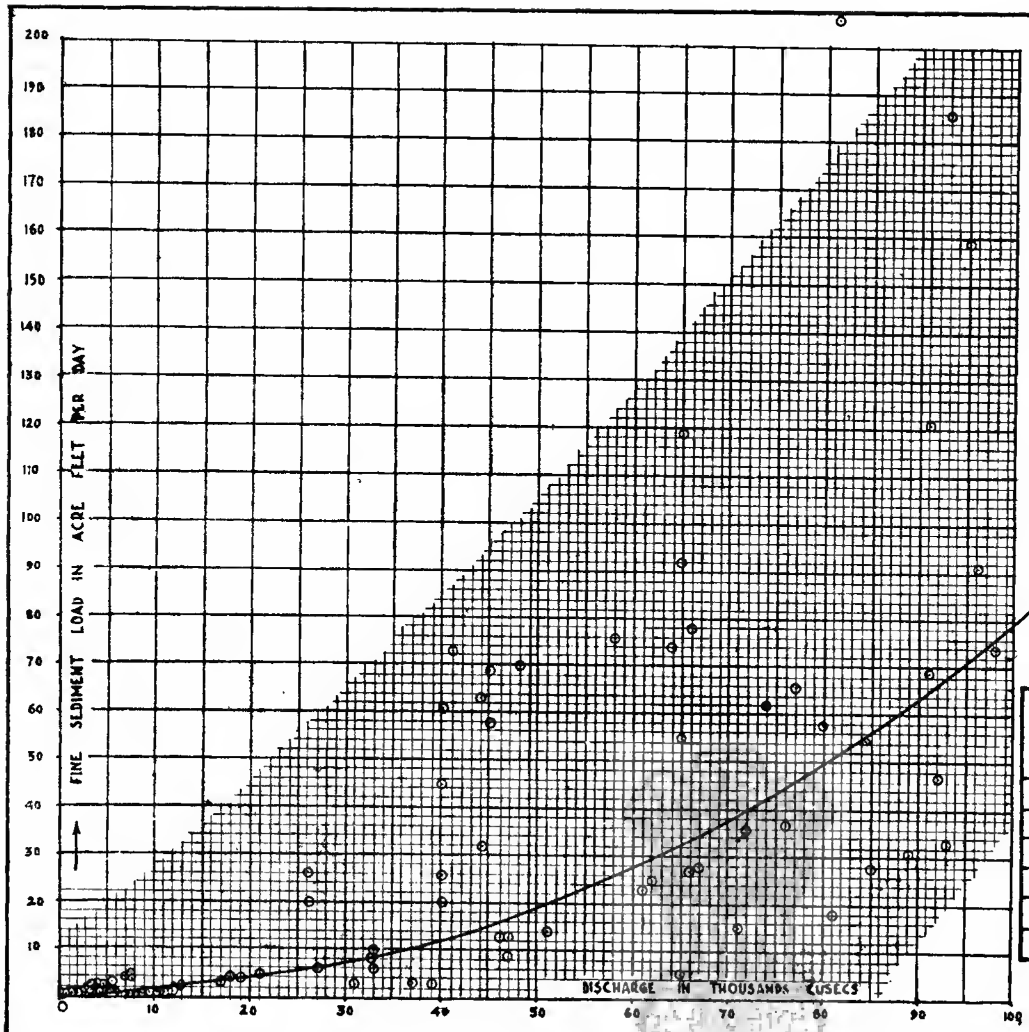


FIG: 5.

FINE SEDIMENT LOAD

0-100 THOUSANDS DISCHARGE RANGE

C.W.I.N.C., NEW DELHI.	
MAHANADI SILT INVESTIGATION AT SAMBALPUR SITE 1947.	
SCALE	
DRAWING No: M—28	DATE:- 2.4.1948.
REFERENCE	
PREPARED BY:-	
TRACED BY:-	
CHECKED BY:- 6/4/48	O.S.D

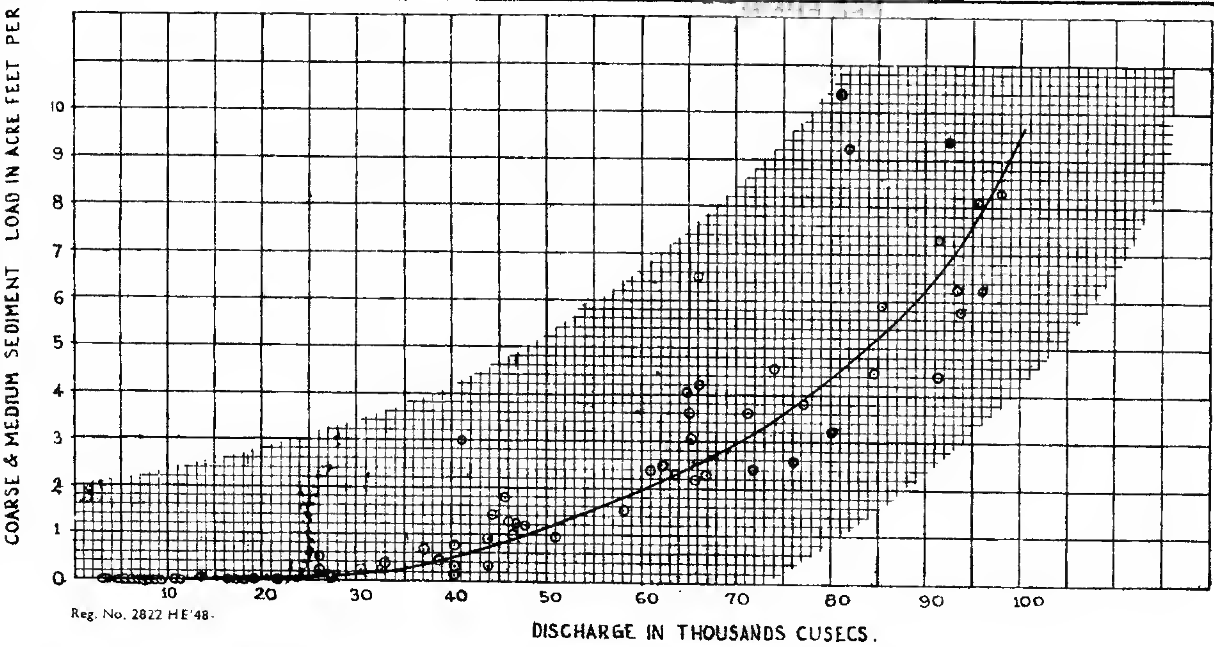


FIG. 5

COARSE & MEDIUM SEDIMENT LOADS

0-100 THOUSANDS DISCHARGE RANGE.

C.W.I.N.C., NEW DELHI.	
MAHANADI SILT INVESTIGATION AT SAMBALPUR SITE. 1947.	
SCALE	
DRAWING No M—26	DATE. 7-4-4
REFERENCE.	
PREPARED BY	
TRACED BY. Chowdhuri	
CHECKED BY	O.S.D

Reg. No. 2822 HE'48.

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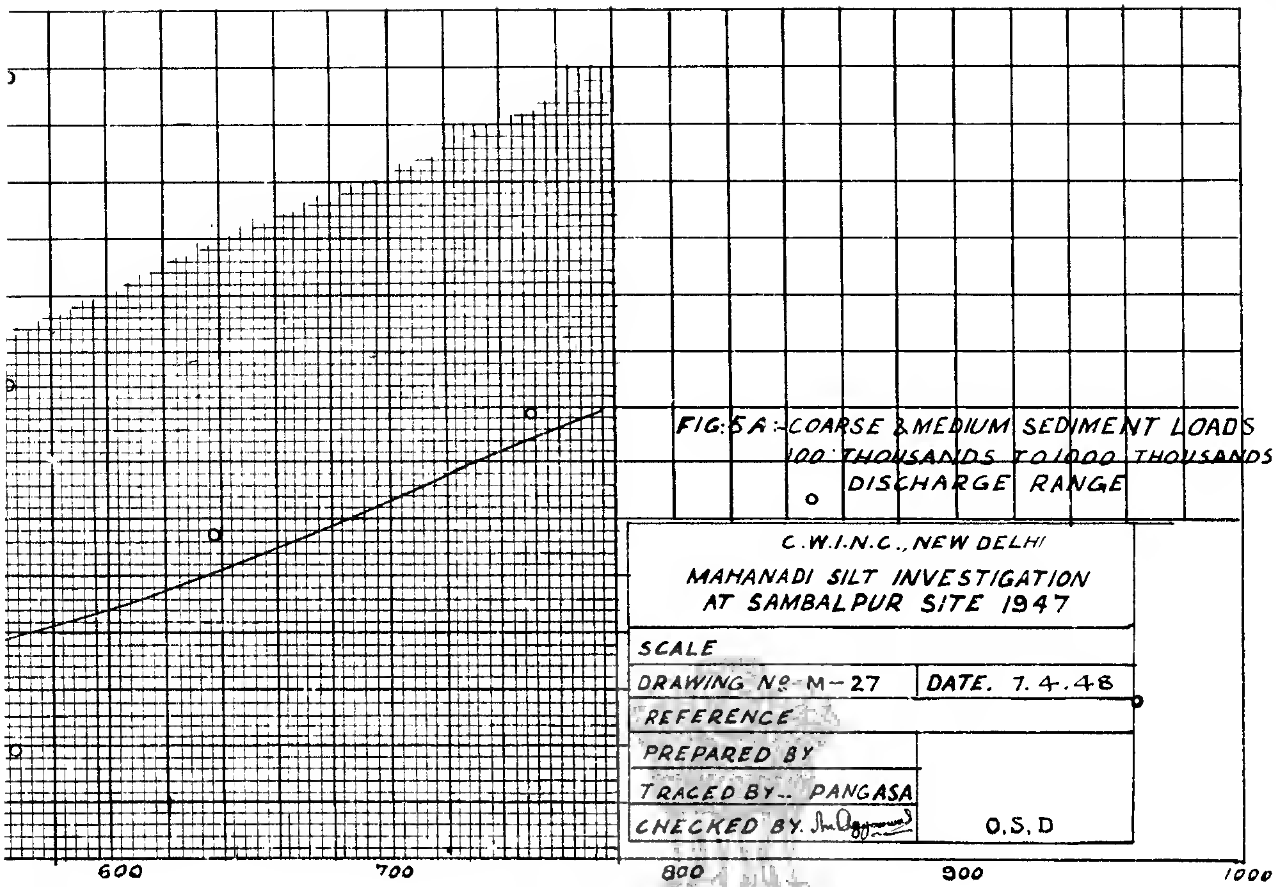

FIG: 5 A:- COARSE & MEDIUM SEDIMENT LOADS 100 THOUSANDS TO 1000 THOUSANDS DISCHARGE RANGE

C.W.I.N.C., NEW DELHI MAHANADI SILT INVESTIGATION AT SAMBALPUR SITE 1947	
SCALE	
DRAWING No. M-27	DATE. 7.4.48
REFERENCE	
PREPARED BY	O.S.D
TRACED BY.. PANGASA	
CHECKED BY. [signature]	

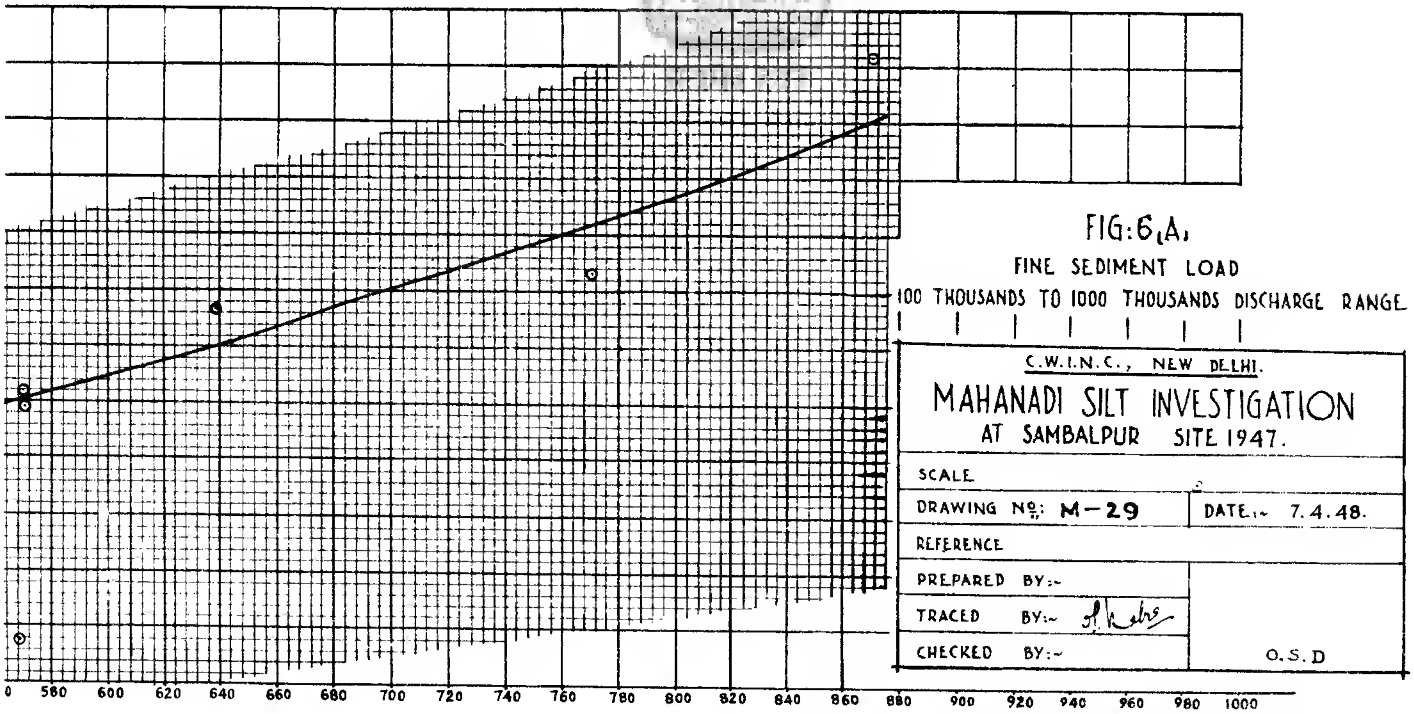

FIG: 6 A.

FINE SEDIMENT LOAD

100 THOUSANDS TO 1000 THOUSANDS DISCHARGE RANGE

C.W.I.N.C., NEW DELHI. MAHANADI SILT INVESTIGATION AT SAMBALPUR SITE 1947.	
SCALE	
DRAWING No.: M-29	DATE.:- 7.4.48.
REFERENCE	
PREPARED BY:-	O.S.D
TRACED BY:- [signature]	
CHECKED BY:-	

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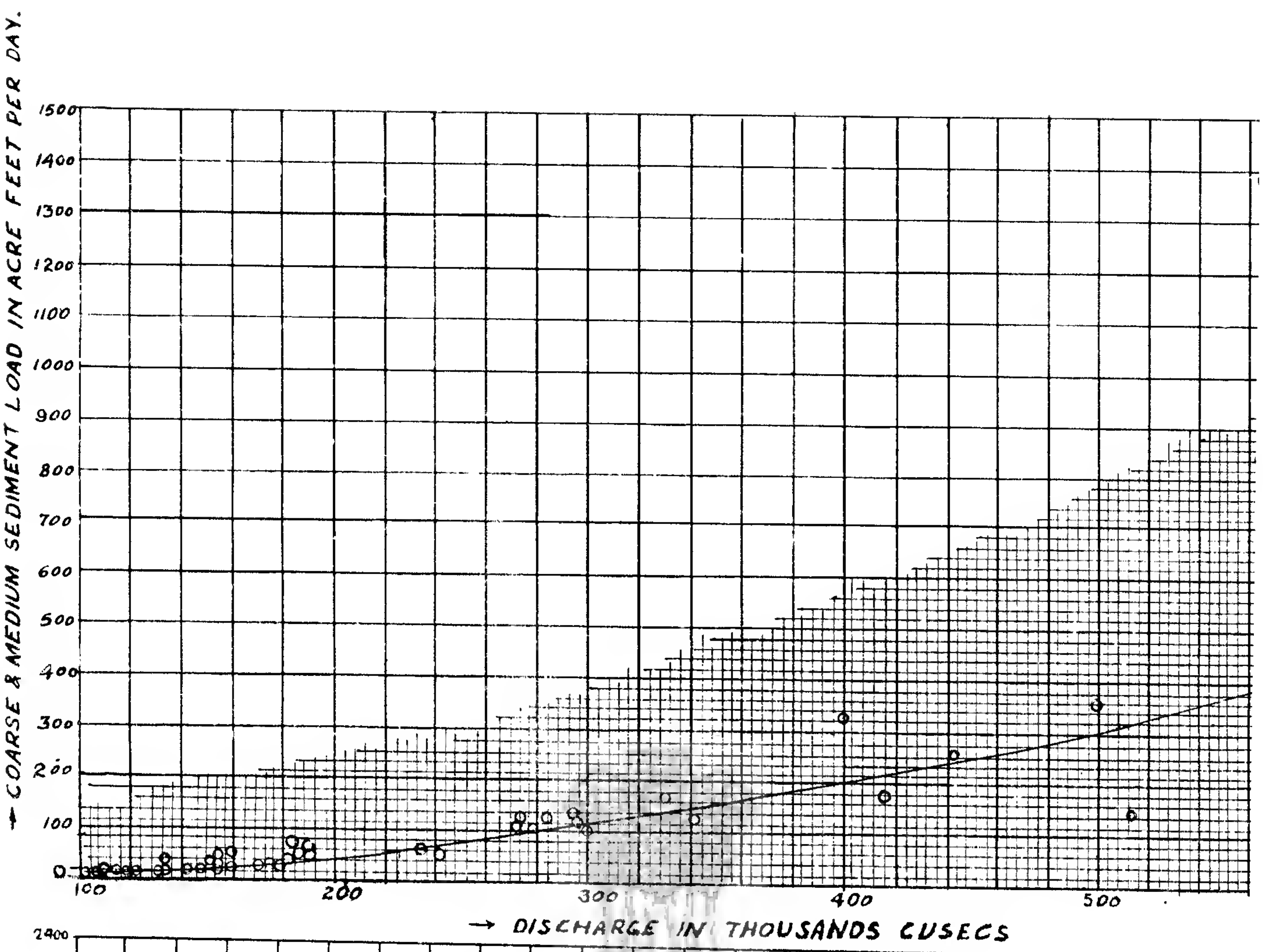
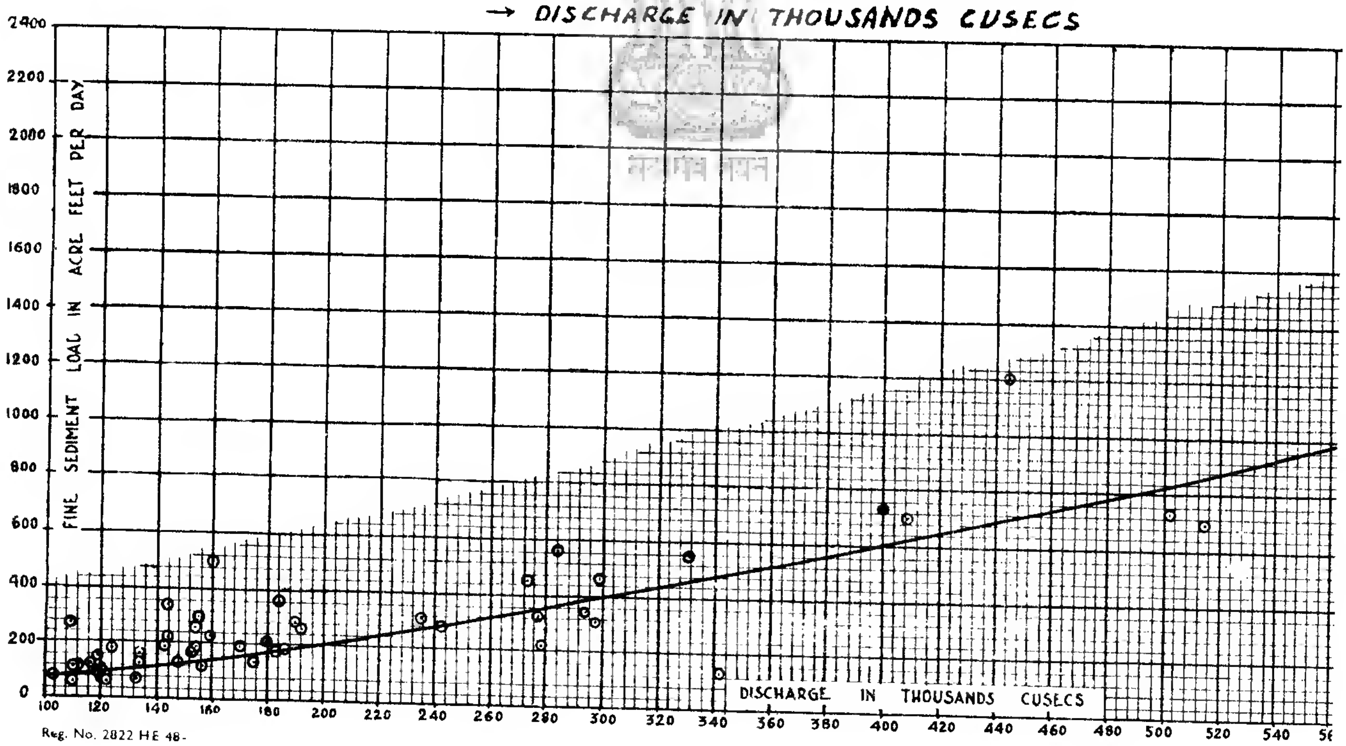
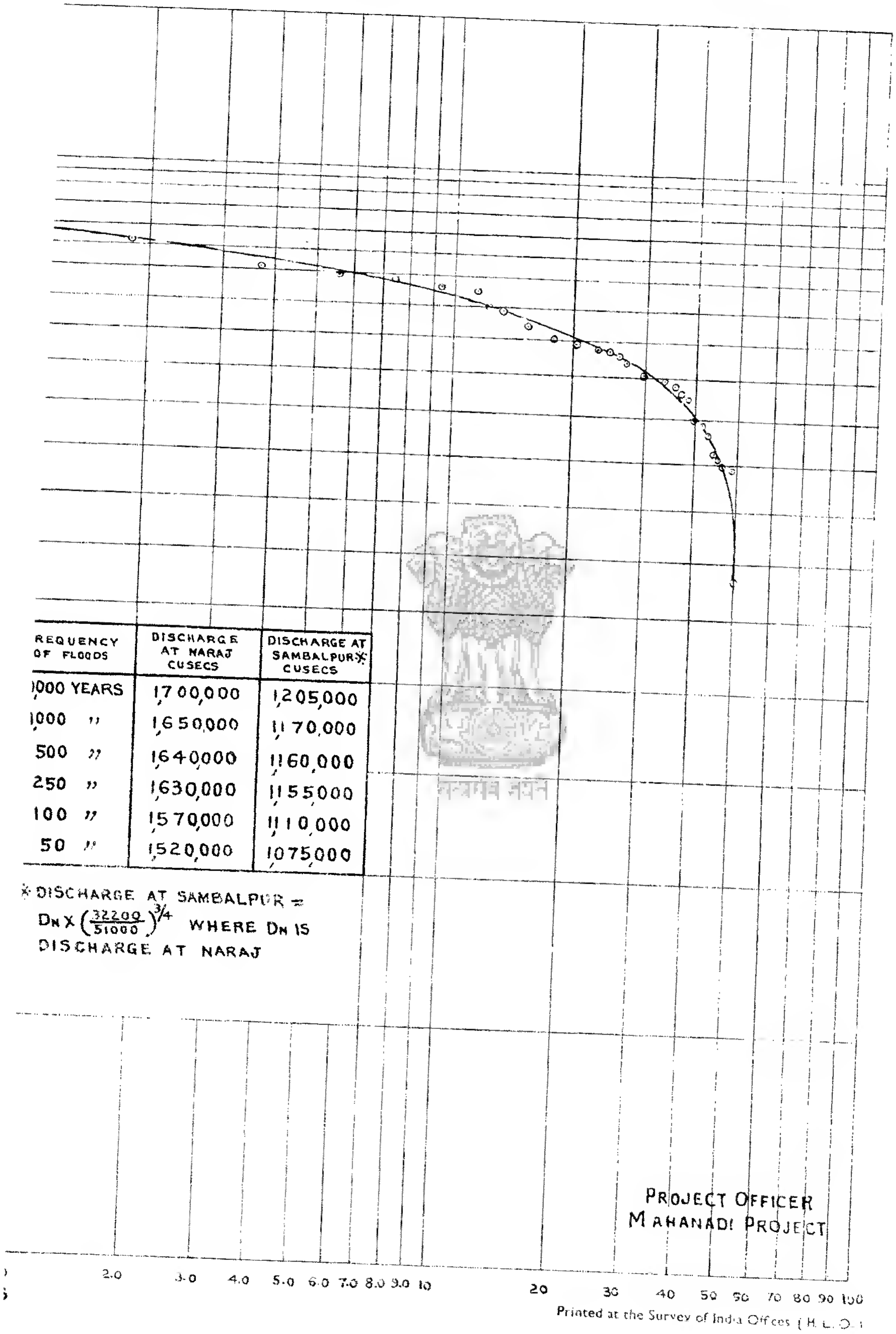




Reg. No. 2822 HE 48-

THE FLOODS OF MAHANADI

ENCLOSURE 3.



FREQUENCY OF FLOODS	DISCHARGE AT NARAJ CUSECS	DISCHARGE AT SAMBALPUR* CUSECS
1000 YEARS	17,00,000	1,205,000
1000 "	1,650,000	1,170,000
500 "	1,640,000	1,160,000
250 "	1,630,000	1,155,000
100 "	1,570,000	1,110,000
50 "	1,520,000	1,075,000

*DISCHARGE AT SAMBALPUR = $D_N \times \left(\frac{32200}{51000}\right)^{3/4}$ WHERE D_N IS DISCHARGE AT NARAJ

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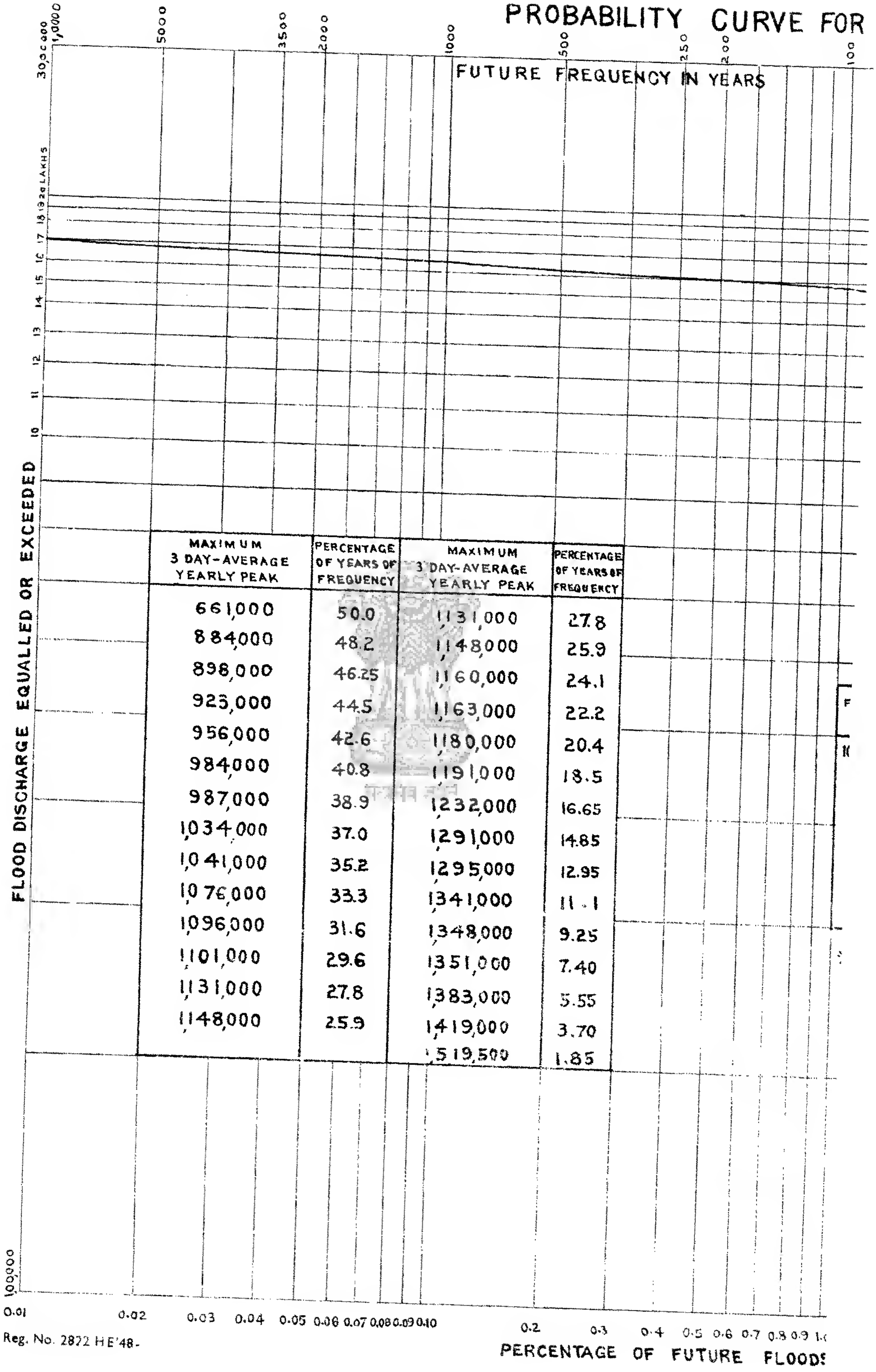
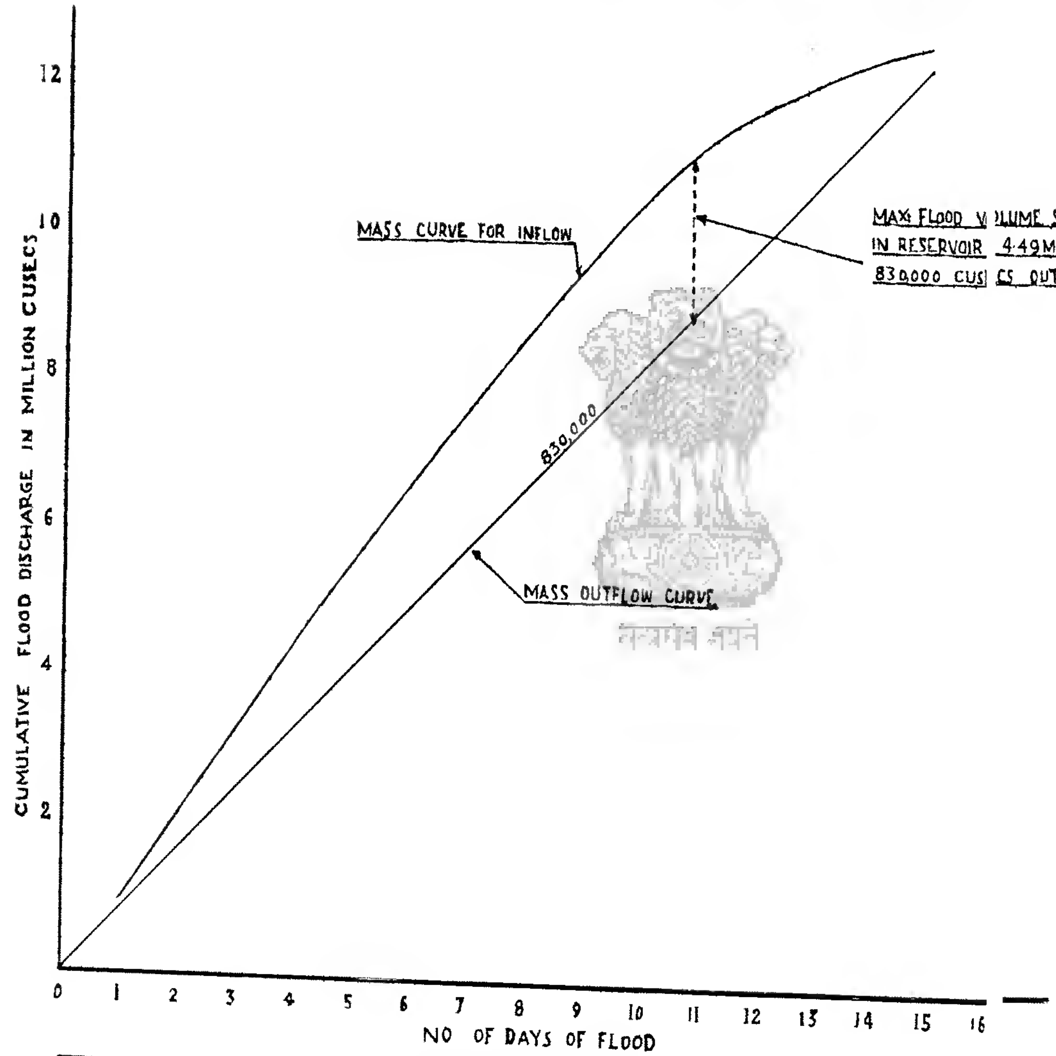
PROBABILITY CURVE FOR



MAXIMUM 3 DAY-AVERAGE YEARLY PEAK	PERCENTAGE OF YEARS OF FREQUENCY	MAXIMUM 3 DAY-AVERAGE YEARLY PEAK	PERCENTAGE OF YEARS OF FREQUENCY
661,000	50.0	1131,000	27.8
884000	48.2	1148000	25.9
898,000	46.25	1160,000	24.1
925,000	44.5	1163,000	22.2
956,000	42.6	1180,000	20.4
984000	40.8	1191,000	18.5
987,000	38.9	1232,000	16.65
1,034,000	37.0	1291,000	14.85
1,041,000	35.2	1295,000	12.95
1,076,000	33.3	1341,000	11.1
1,096,000	31.6	1348,000	9.25
1,101,000	29.6	1351,000	7.40
1,131,000	27.8	1383,000	5.55
1148,000	25.9	1419,000	3.70
		1519,500	1.85

Reg. No. 2872 H E'48-

MASS CURVES FOR INFLOW AND OUTFLOW FOR A 10,000 YEAR FLOOD OF 1205000 CUSECS PEAK INFLOW INTO HIRAKUD RESERVOIR



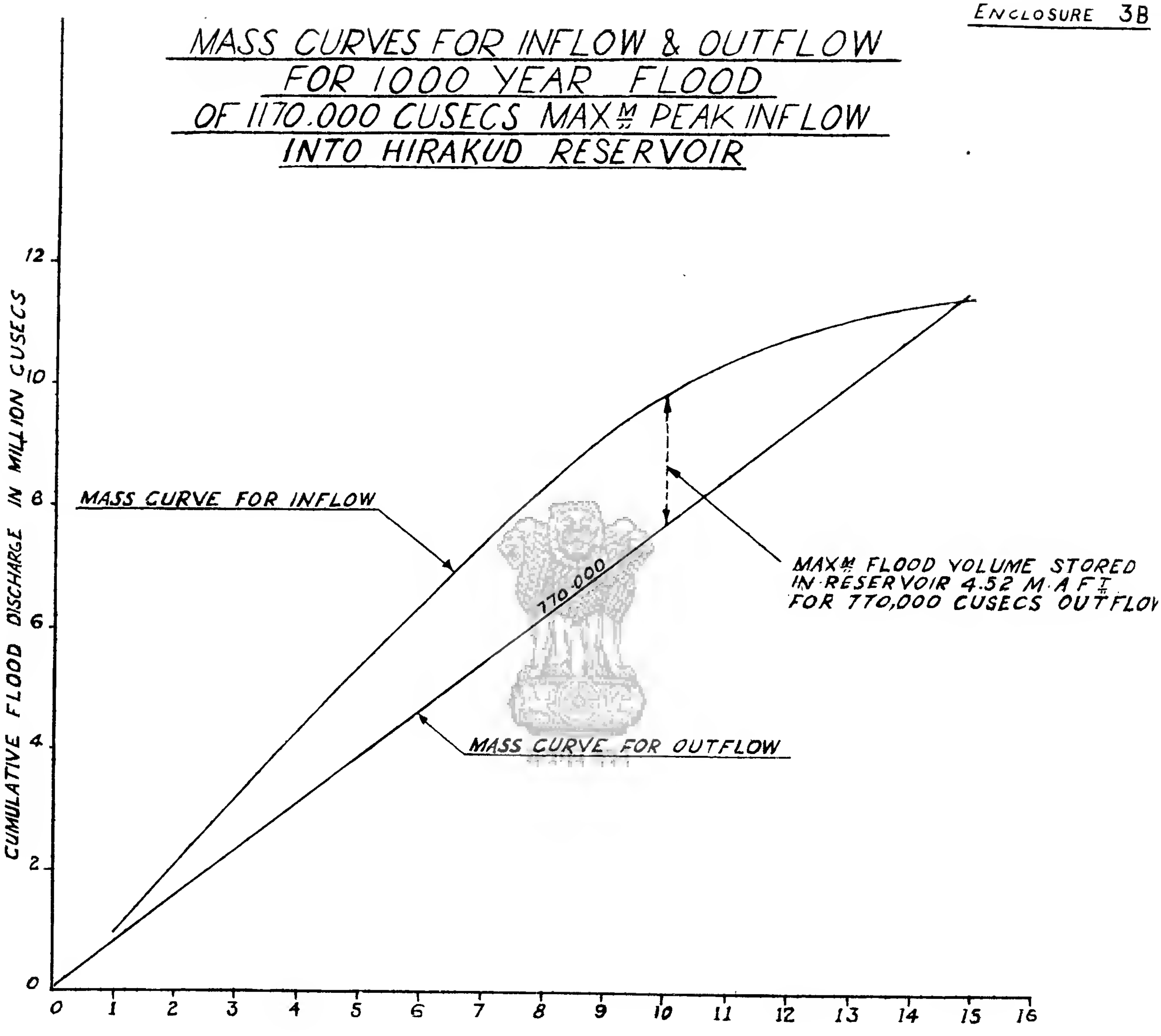
QUANTITY DISCHARGED DAILY CUSECS	ACCUMULATED BALANCE IN RESERVOIR CUSEC-DAYS	CUMULATIVE FLOOD VOLUME M.A.FT.	MAXIMUM RESERVOIR LEVEL
830,000	2,245,000	4.49	630.0

Reg. No. 2822 H.E.'48.

Printed at the Survey of India Offices (H. L. O.).

ENCLOSURE 3B

MASS CURVES FOR INFLOW & OUTFLOW FOR 1000 YEAR FLOOD OF 1170.000 CUSECS MAX^{M} PEAK INFLOW INTO HIRAKUD RESERVOIR



QUANTITY DISCHARGED DAILY CUSECS	ACCUMULATED BALANCE IN RESERVOIR CUSEC DAYS	CUMULATIVE FLOOD VOLUME M.A.H	MAXIMUM RESERVOIR LEVEL R.L.
770,000	2,260,000	4.52	630.0

Reg. No 2822 HE'48-

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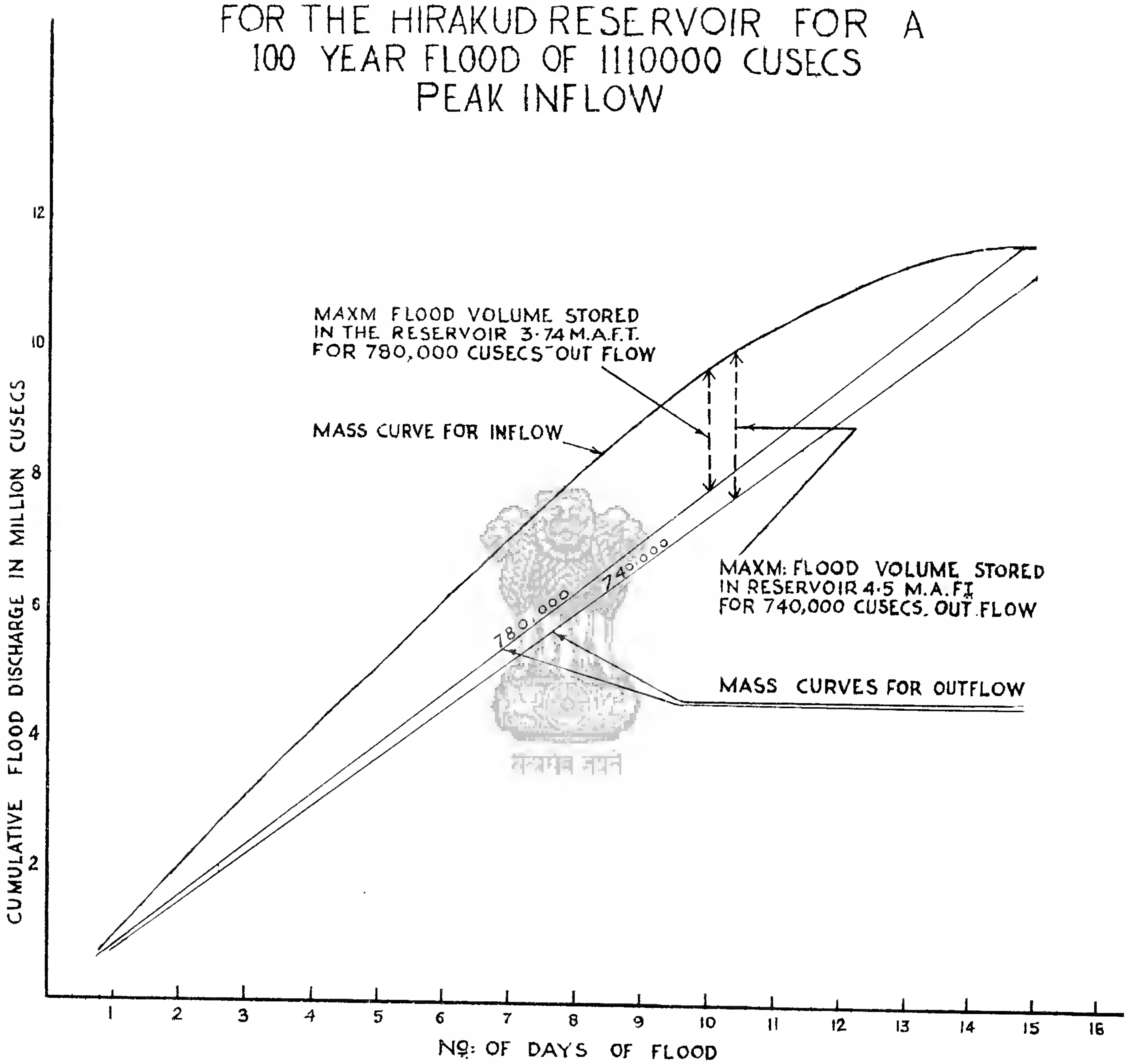
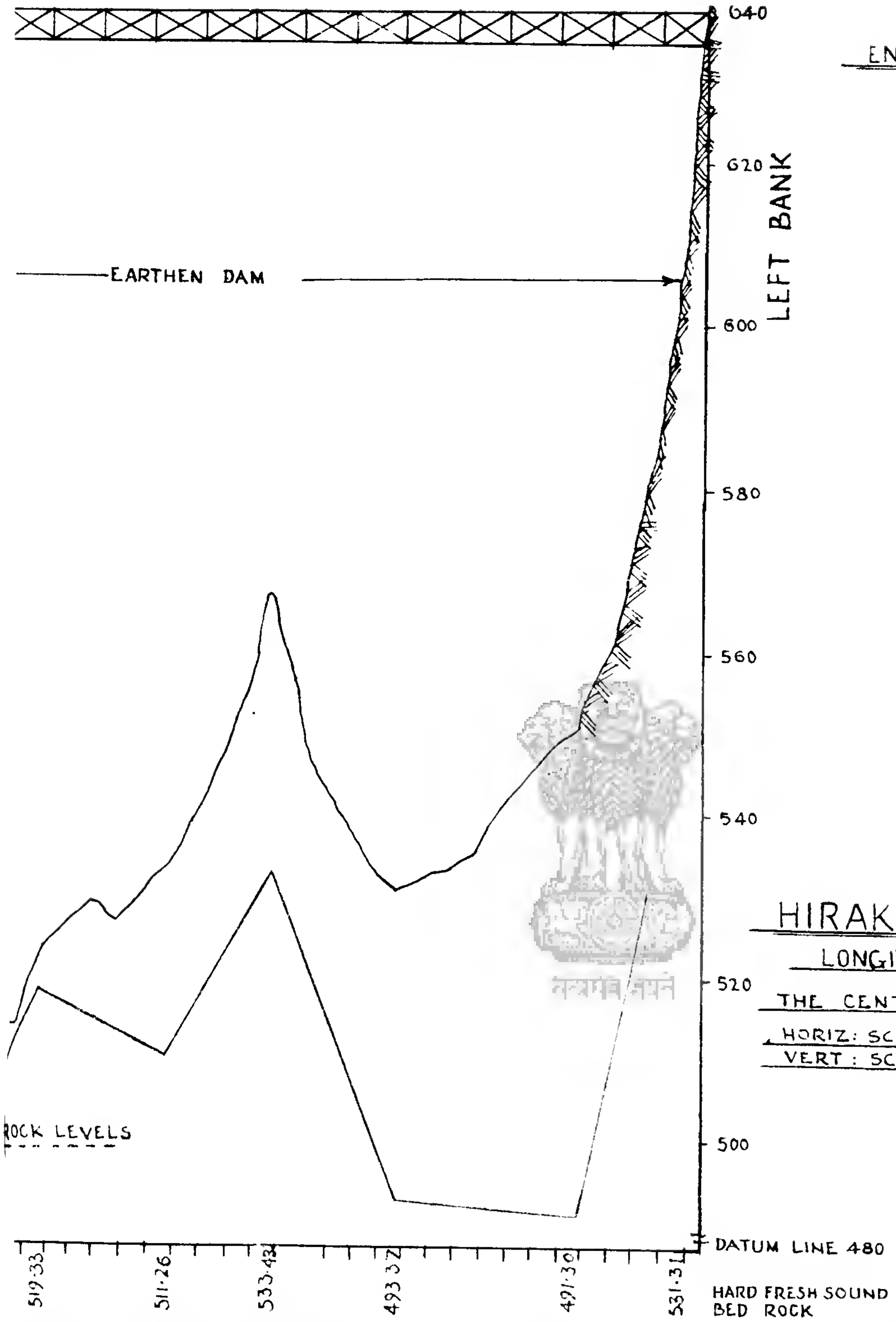
MASS CURVES FOR INFLOW AND OUTFLOW FOR THE HIRAKUD RESERVOIR FOR A 100 YEAR FLOOD OF 1110000 CUSECS PEAK INFLOW



QUANTITY DAILY DISCHARGED CUSECS	ACCUMULATED BALANCE IN RESERVOIR CUSEC DAYS	CUMULATIVE FLOOD VOLUME M.A.H.	MAXIMUM RESERVOIR LEVEL R.L.
740.000	2255000	4·51	630·0
780.000	1870000	3·74	625·0

ENCLOSURE NO 4



R.D.	N.S. LEVEL
2700	514·72
2600	523·71
2500	527·43
2400	530·43
2300	527·96
2200	531·21
2100	534·08
2000	540·15
1900	547·03
1800	555·37
1700	567·80
1600	555·14
1500	544·44
1400	539·24
1300	534·16
1200	531·68
1100	532·99
1000	533·80
900	537·80
800	541·48
700	545·32
600	548·74
500	551·40
400	559·36
300	571·43
200	586·80
100	610·57
0	640·43

HIRAKUD DAM PROJECT

LONGITUDINAL SECTION ALONG THE CENTRE LINE OF THE DAM

HORIZ: SCALE – 1" = 546·62 FT.
VERT: SCALE – 1" = 16·843 FT.

[signature]
7·6·48.
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MAHANADI PROJECT.

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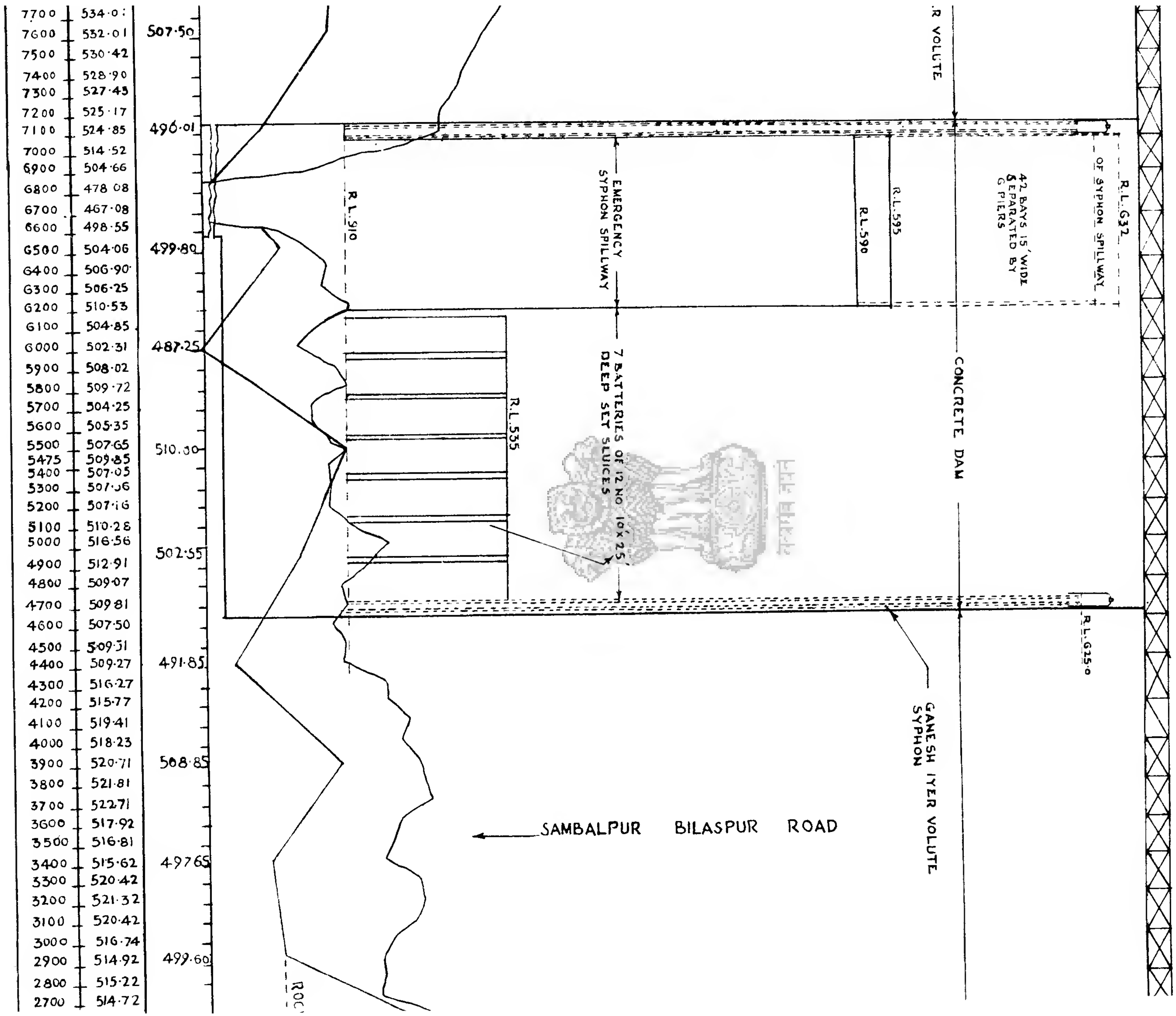
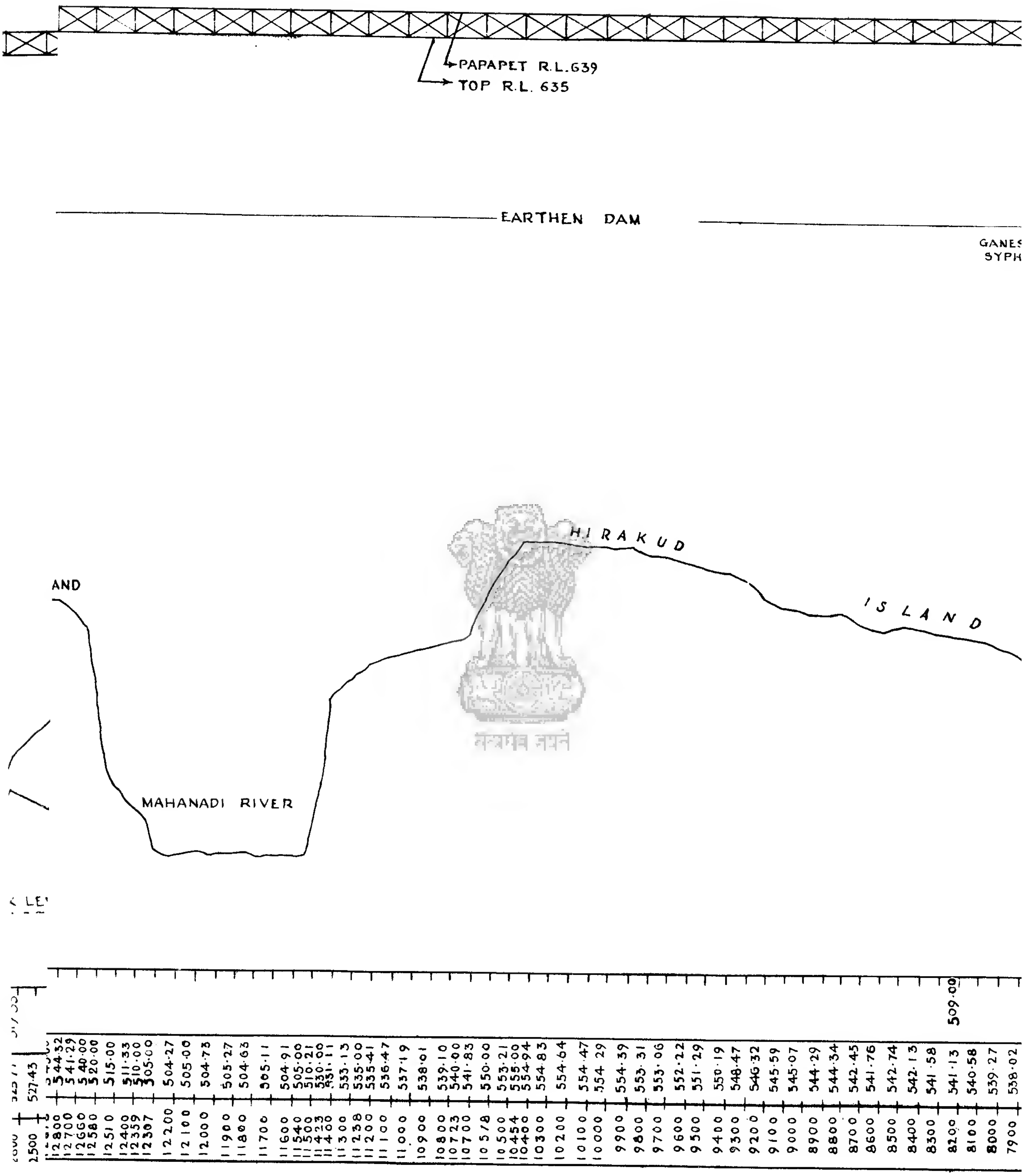
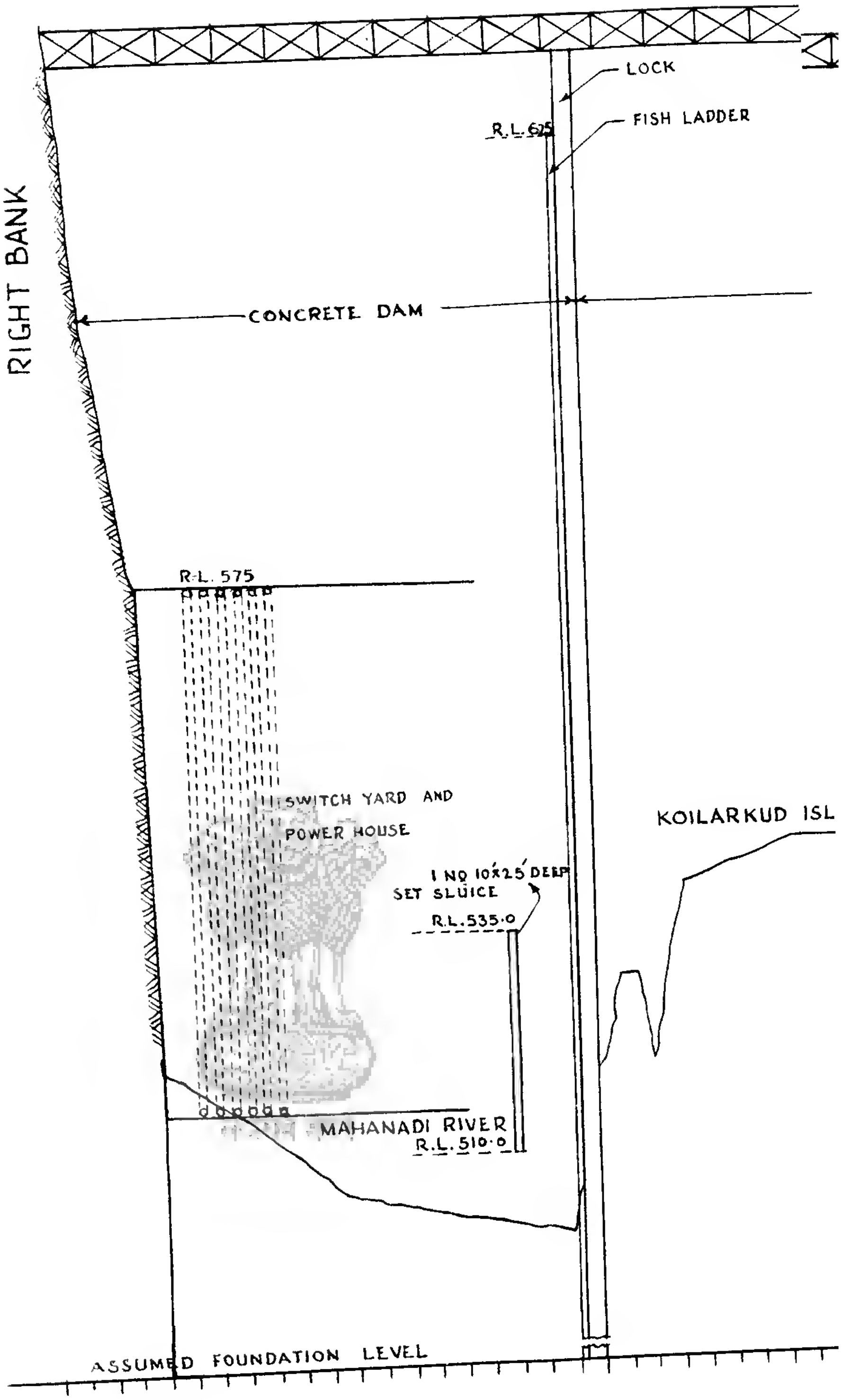


SAMBALPUR BILASPUR ROAD
CONCRETE DAM
7 BATTERIES OF 12 NO 10'x 25' DEEP SET SLUICES
EMERGENCY SYPHON SPILLWAY
42 BAYS 15' WIDE SEPARATED BY G PIERS
OF SYPHON SPILLWAY
GANESH IYER VOLUTE SYPHON
R VOLUTE
R.L.910
R.L.535
R.L.590
R.L.595
R.L.632
R.L.625·0
507·50
496·01
499·80
487·25
510·30
502·55
491·85
508·85
497·65
499·60
ROC
7700 534·0
7600 532·01
7500 530·42
7400 528·90
7300 527·45
7200 525·17
7100 524·85
7000 514·52
6900 504·66
6800 478·08
6700 467·08
6600 498·55
6500 504·06
6400 506·90
6300 506·25
6200 510·53
6100 504·85
6000 502·31
5900 508·02
5800 509·72
5700 504·25
5600 505·35
5500 507·65
5475 509·85
5400 507·05
5300 507·06
5200 507·16
5100 510·28
5000 516·56
4900 512·91
4800 509·07
4700 509·81
4600 507·50
4500 509·31
4400 509·27
4300 516·27
4200 515·77
4100 519·41
4000 518·23
3900 520·71
3800 521·81
3700 522·71
3600 517·92
3500 516·81
3400 515·62
3300 520·42
3200 521·32
3100 520·42
3000 516·74
2900 514·92
2800 515·22
2700 514·72


PAPAPET R.L.639
TOP R.L. 635
EARTHEN DAM
HIRAKUD
ISLAND
MAHANADI RIVER
509.00



670.00	15770
640.00	15727
596.00	15600
525.00	15517
520.00	15400
518.10	15300
516.13	15200
514.21	15110
511.93	15000
510.00	14905
507.01	14800
505.00	14720
504.89	14680
504.00	14600
503.51	14500
502.61	14400
502.00	14300
501.77	14200
501.13	14100
500.47	14000
500.00	13890
516.00	13800
530.00	13683
530.00	13642
520.00	13573
540.00	13446
540.47	13400
541.97	13300
542.83	13200
543.93	13100
545.00	13034
545.06	13000

PREPARED BY Agarwal
TRACED BY SSK
CHECKED BY Agarwal 9.6.48.

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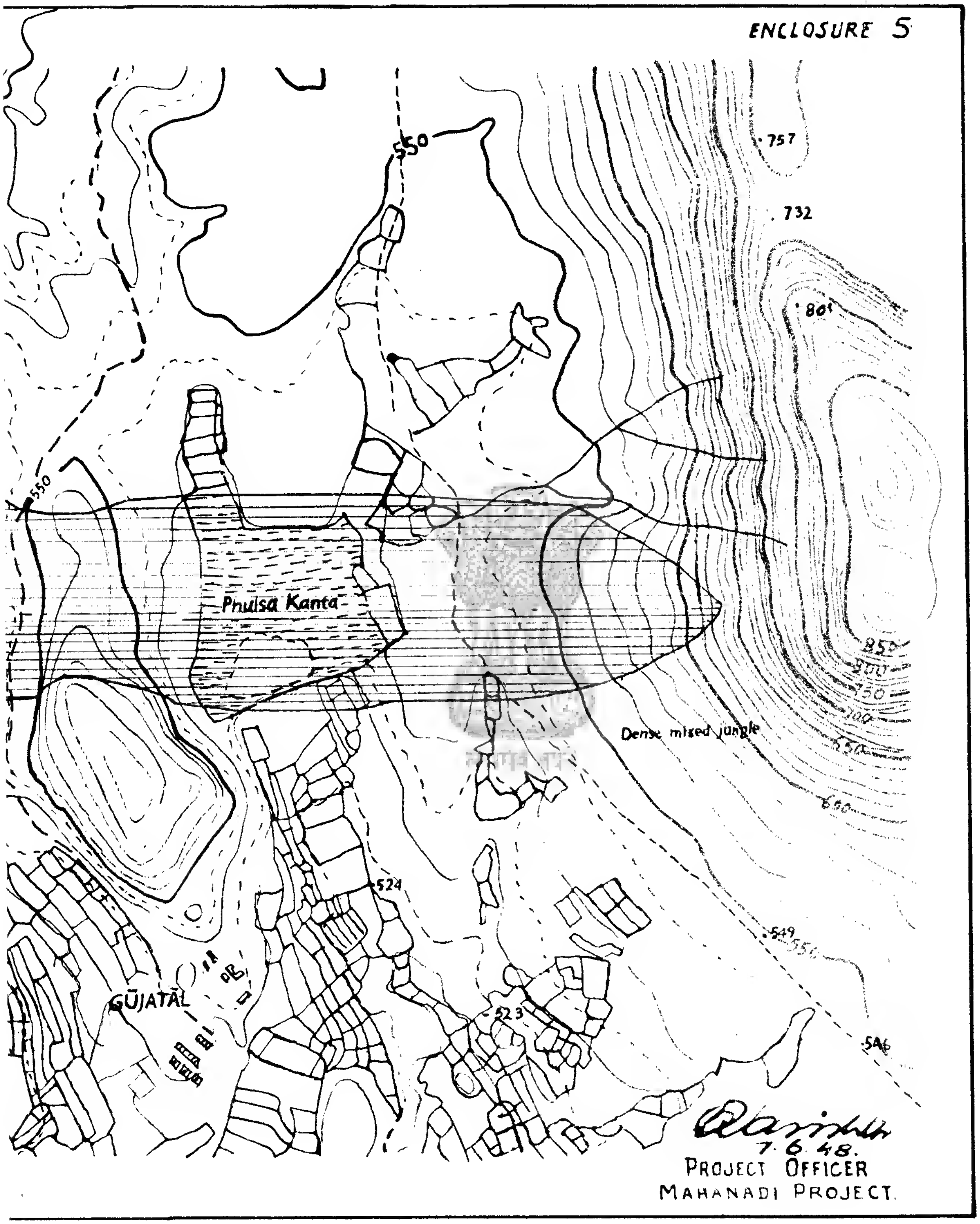

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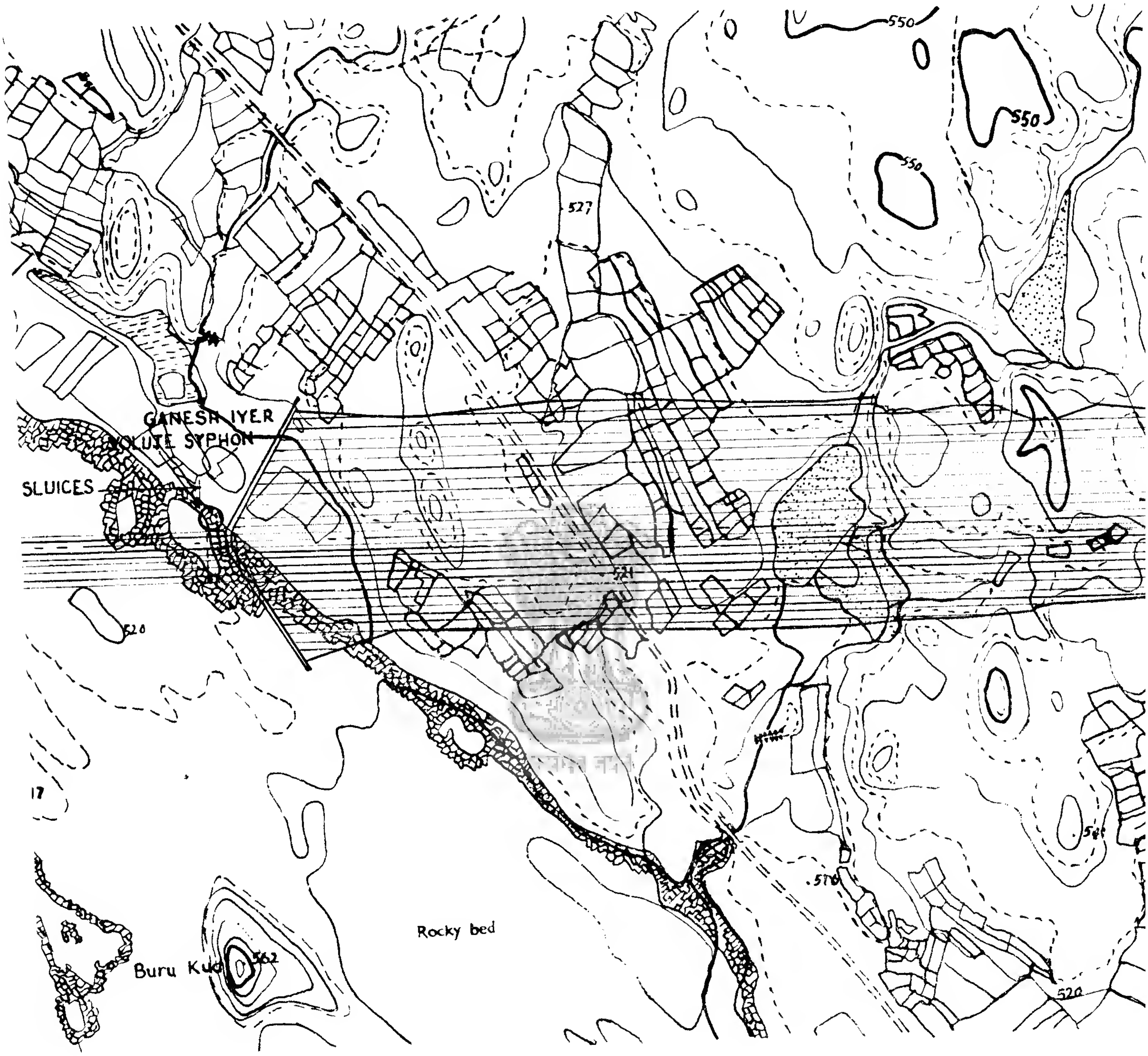

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527
GANESH IYER
VOLUTE SYPHON
SLUICES
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520
517
510
Rocky bed
Buru Kud
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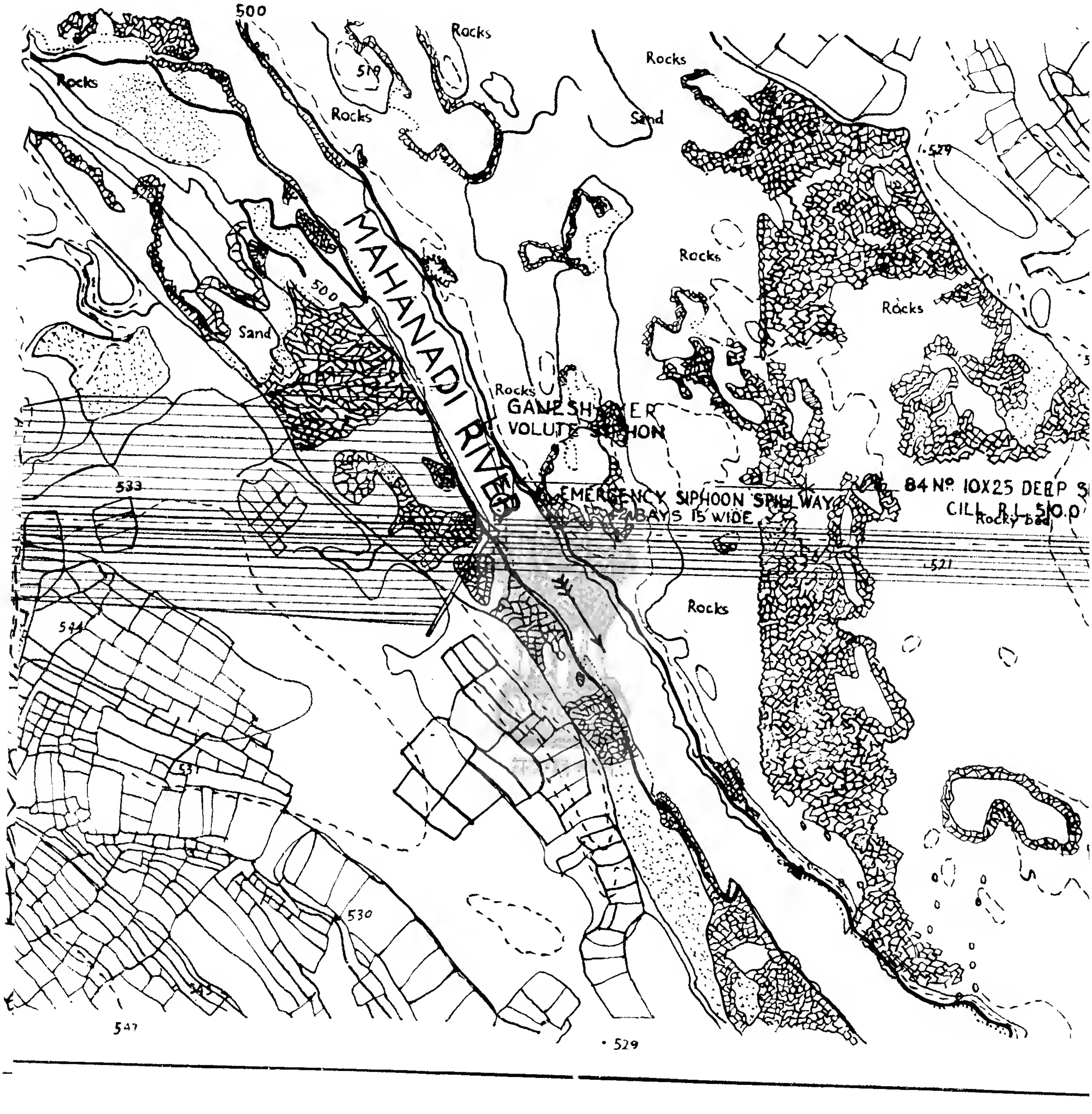
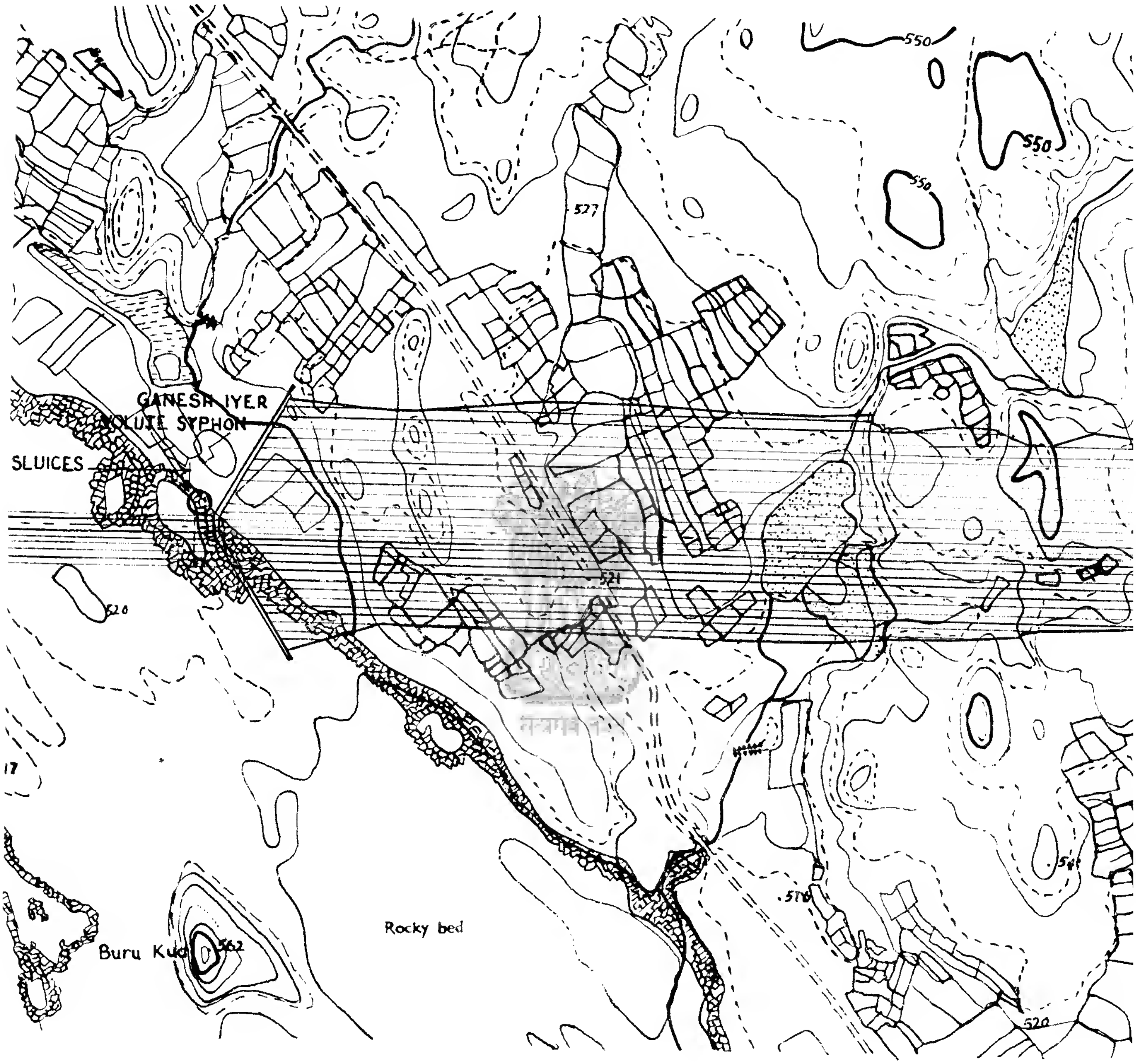
520



500
Rocks
519
Rocks
Rocks
Rocks
Sand
529
Rocks
Rocks
500
MAHANADI RIVER
Sand
Rocks
GANESH RIVER
VOLUTE SIPHON
533
EMERGENCY SIPHOON SPILLWAY
BAYS 15 WIDE
84 Nº 10X25 DEEP
CILL R.L 510.0
Rocky bed
521
Rocks
544
530
529



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Rocky bed
Buru Kud
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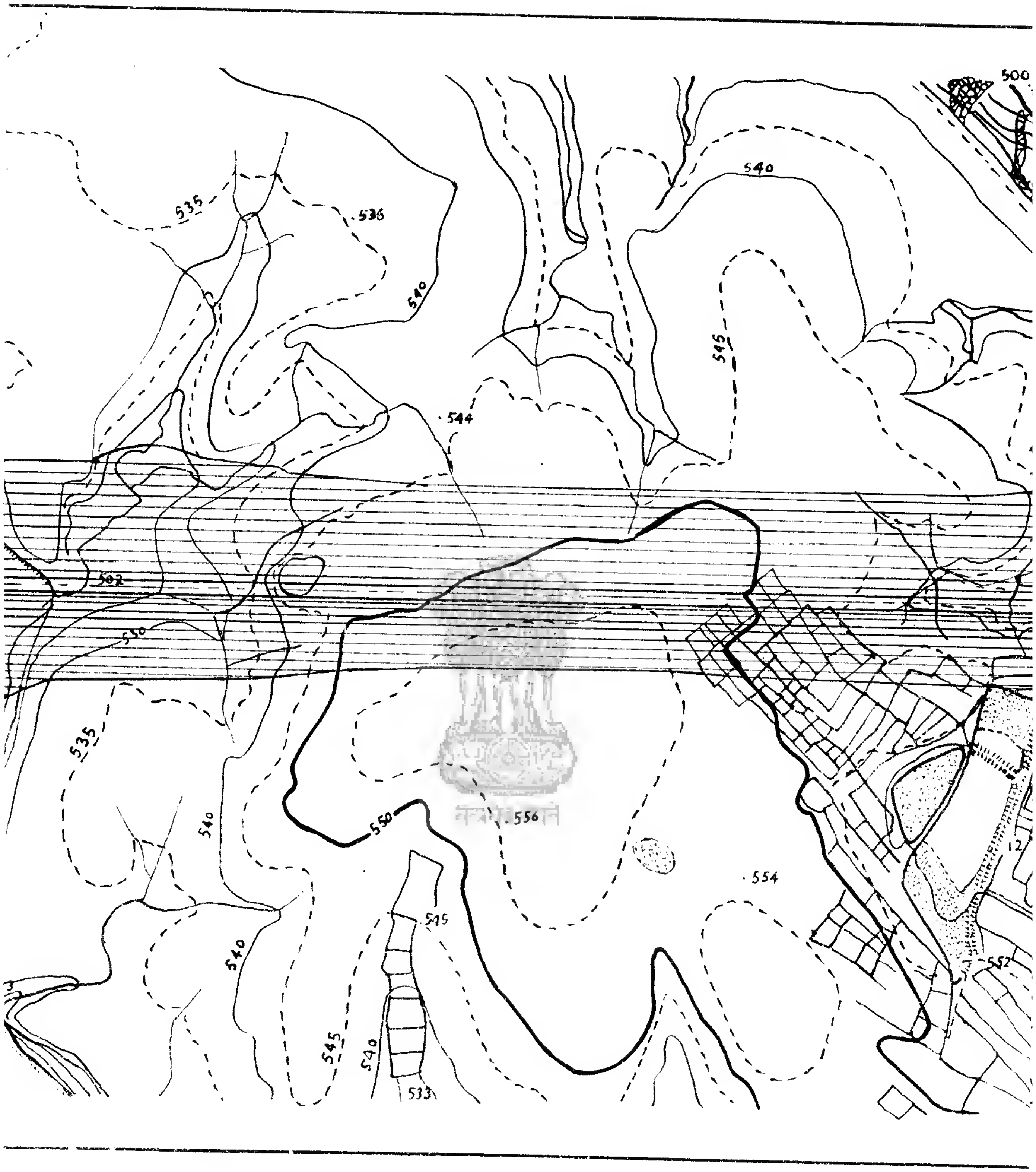
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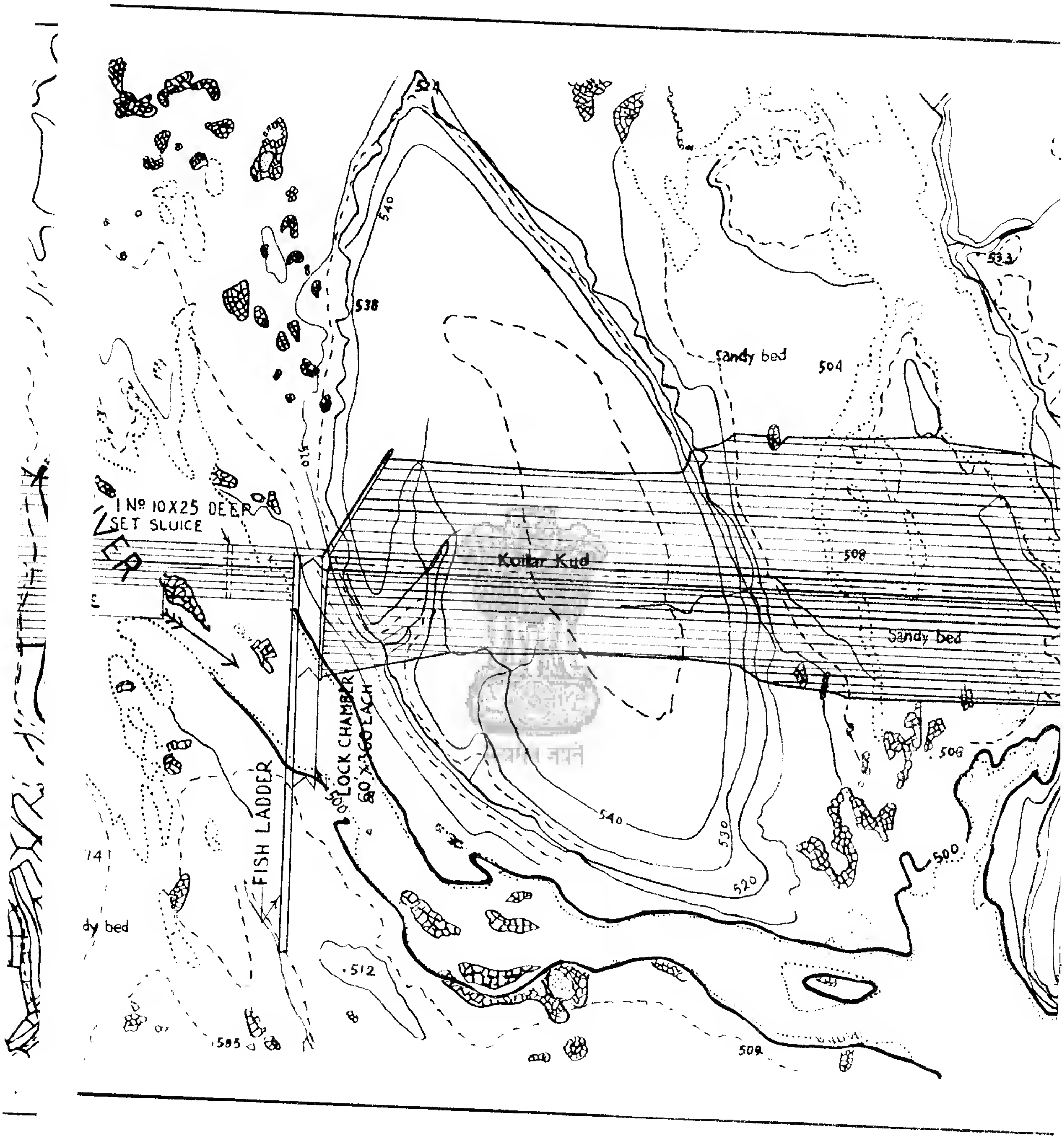
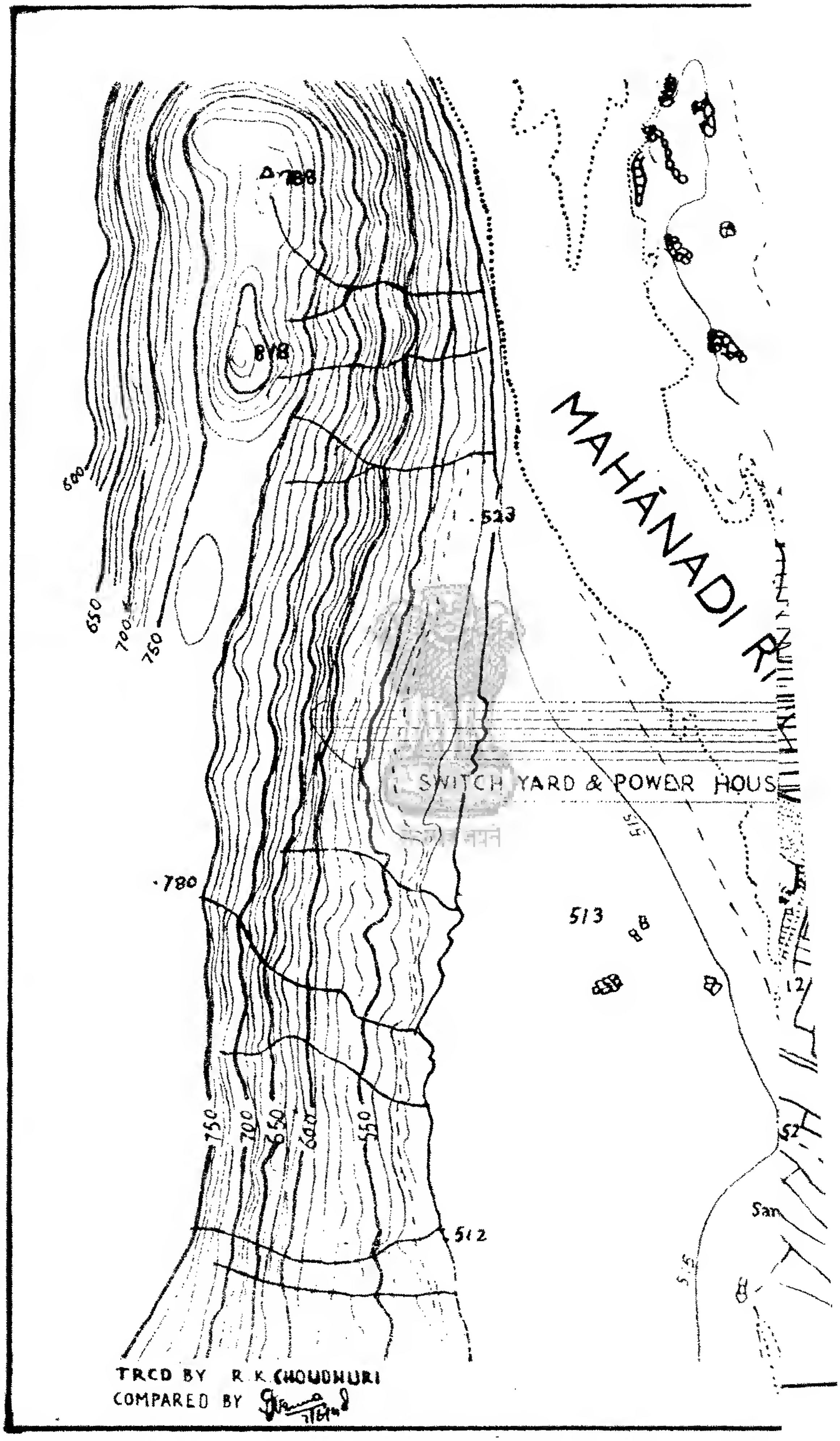


524
540
538
510
1 Nº 10X25 DEEP
SET SLUICE
ER
Koilar Kud
LOCK CHAMBER
60'X36 GOLACH
FISH LADDER
540
530
520
Sandy bed
504
533
508
Sandy bed
506
500
512
505
509
dy bed



Reg. No 2822 HE'48

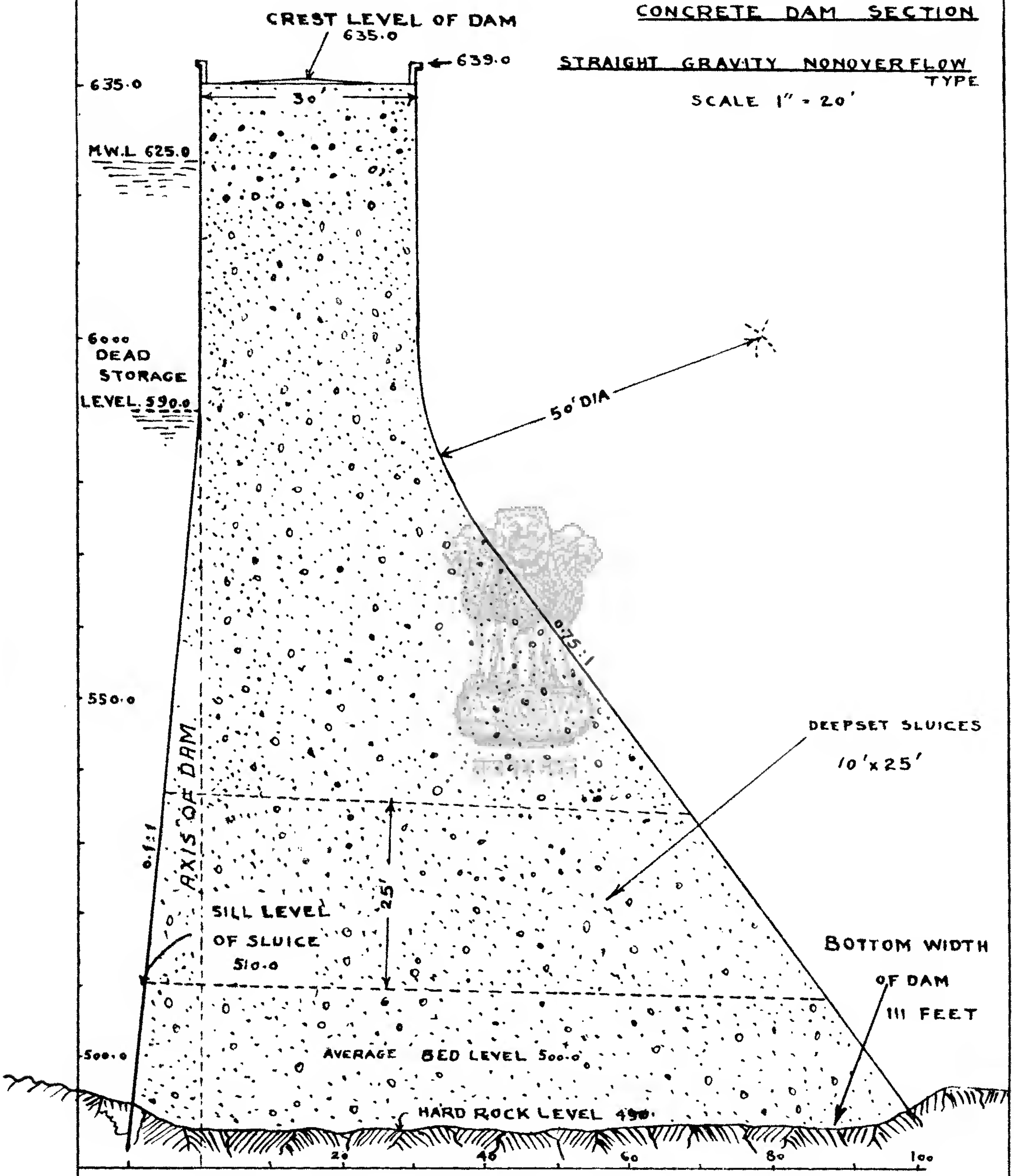
ENCLOSURE 6

HIRAKUD DAM PROJECT

CONCRETE DAM SECTION

STRAIGHT GRAVITY NONOVERFLOW TYPE

SCALE 1" = 20'



TRACED BY: Kishinchand. S.M.
5.6.48

Compared by, [signature] 4.6.48.

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MAHANADI PROJECT.

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ENCLOSURE 7.

NOTE ON THE SUITABILITY OF SOILS IN THE PROXIMITY OF THE CENTRAL AXIS OF THE HIRAKUD DAM FOR THE CONSTRUCTION OF THE EARTHEN DAM.

BY

Dr. R. C. Hoon MSc. Ph.D. Officer on Special Duty.

Introductory.

The following report is based on the results of the analyses of the soils from the test pits and borrow area 1 (two samples from borrow area 2 also). The soil samples were examined for :

(*i*) Separation into coarse and fine fractions and their particle size distribution ;

(*ii*) Compaction and penetration resistance ;

(*iii*) Direct Shear ;

(*iv*) Liquid limit, plastic limit and plasticity index. (of a few typical samples).

Main Characteristics of Soils Examined.

From soils examined in the laboratory for the tests mentioned above, they can be, broadly speaking, put into two distinct classes. One of the types can be designated as sandy gravel or gravelly sand ; *i.e.*, has a preponderance of coarse sand and gravel and a deficiency of fines. The second type is sandy loam or sandy clayey loam, *i.e.*, has a preponderance of fine sand with a fair clay percentage but is deficient in silt, coarse sand and gravel fractions. The limits of the various characteristics obtainable for the two above mentioned classes of soils are given in the following Table :—

Soil characteristics.	*Limits obtainable in soil tested and designated as*	
	Sandy loam or sandy clayey loam.	Sandy gravel or gravelly sand.
1	2	3
(A) *Grading, i.e., percentage contents of :—*		
Clay	12—28	3—12
Silt	7—25	4—10
Fine Sand	28—71	3—30
Coarse Sand	5—34	5—37
Gravel & Cobbles	Gravel within certain small limits only.	21—72
(B) *Bulk density : lbs/cu. ft—*		
Wet density	114—133	128—140
Dry density	104—117	115—125
Optimum moisture content (%)	10—14	12—18
(C) *Shear Test—*		
Angle of internal friction	35°—50°	36°—63°
Cohesion	565—950	440—850

The Suitability of the Soils for the Construction of the Impermeable and Semipermeable Sections of the Earthen Dam.

(*a*) *Impervious section.*—For soils suitable for use in the construction of the impervious section of the dam, C.H. Lee of the State Rivers and Water Supply Commission Victoria, has specified two limiting curves [fig. 1 (A) & (B)] and it is desirable that the grading of the soil for use in the impervious section should lie between those two curves and approximate to their general slope (as Curve E Fig. 1). The curves for two of our typical soils, one of each of the two classes of soils mentioned above are also plotted in the same Figure [marked (C) & (D)]. It is clear from the proximity of the curves (C) & (D) to curves (A) & (B) that

the Hirakud soils lie towards the ends of the region demarcated by Lee as suitable for use in the impervious section of the dam. Therefore, to obtain best results from the material (curve D) available, a suitable admixture of coarse fraction with existing loamy soil will considerably improve their qualities for their use in the impervious section.

For the impermeable section of the earth dam, it is desirable that the co-efficient of permeability should not exceed one ft. per year. Although experiments in this direction have not yet fully matured, it is expected that Hirakud soils falling within the region specified by Lee, when fully compacted, may also afford the above rate of permeability.

The main characteristics of soils suitable for the impervious portion will be somewhat similar to those given in column 2 of the above Table.

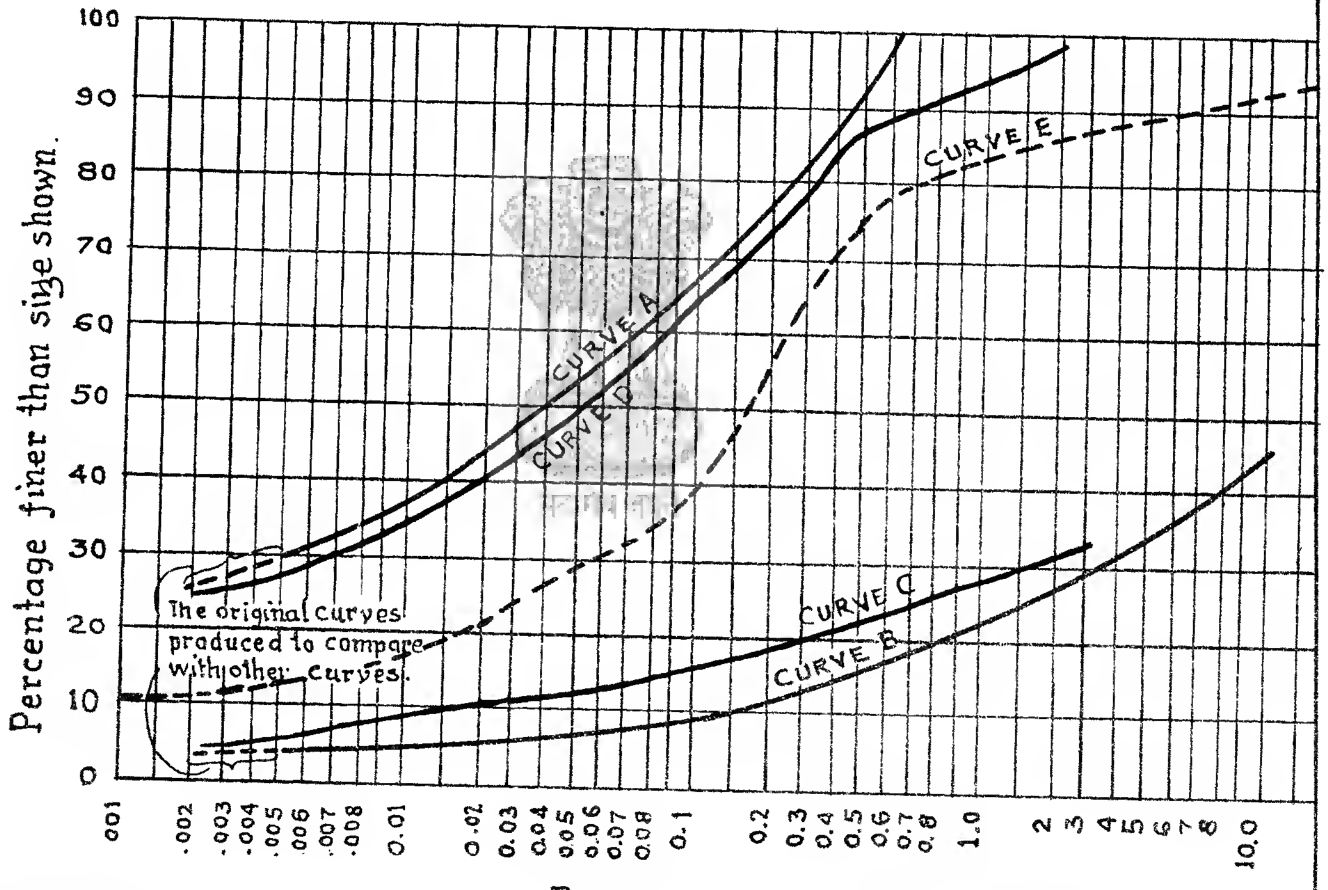
(b) *Semipervious section*.—Soils yielding a curve of the type of curve (B) or in the region below that curve are suitable for use in semipermeable portion of the earthen dam. Those soils will have characteristics similar to those specified in column 3 of the table given above.

ENCLOSURE 7

NOTE :-

CURVES C & D ARE FOR TEST PITS & BORROW AREA SOILS RESPECTIVELY OF THE HIRAKUD REGION.

FIG 1



TRCD. BY: G.R. Chaudhry 7.5.48

COMPARED BY: [signature] 7/6/48.

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O.S.D.

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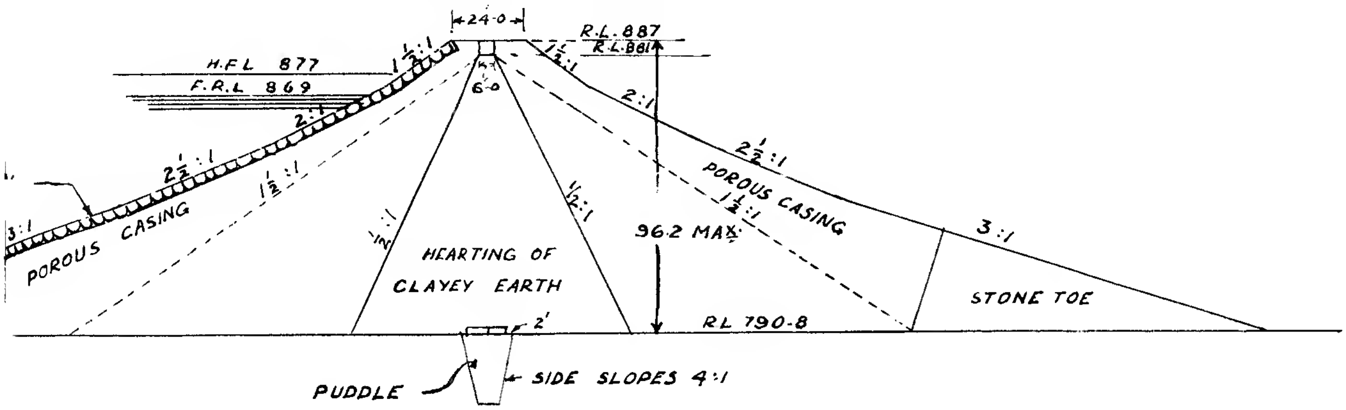
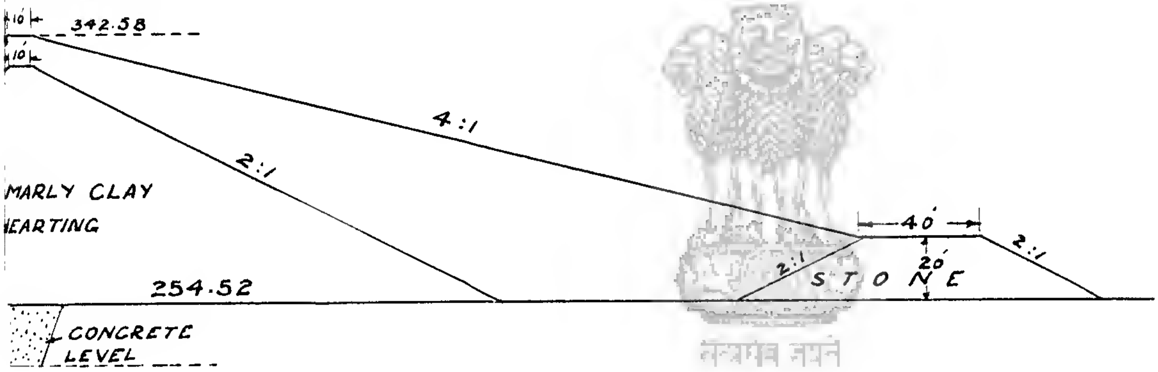
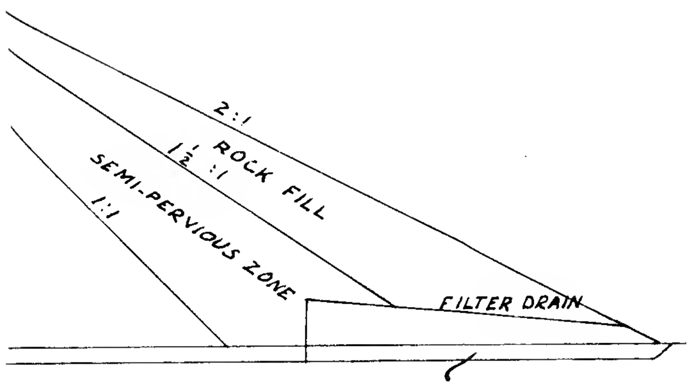
ENCLOSURE 8

HARSI DAM, GWALIOR STATE



DAM, MADRAS PRESIDENCY





SECTIONS OF EARTH DAMS

SCALE: 1" = 50 FT.

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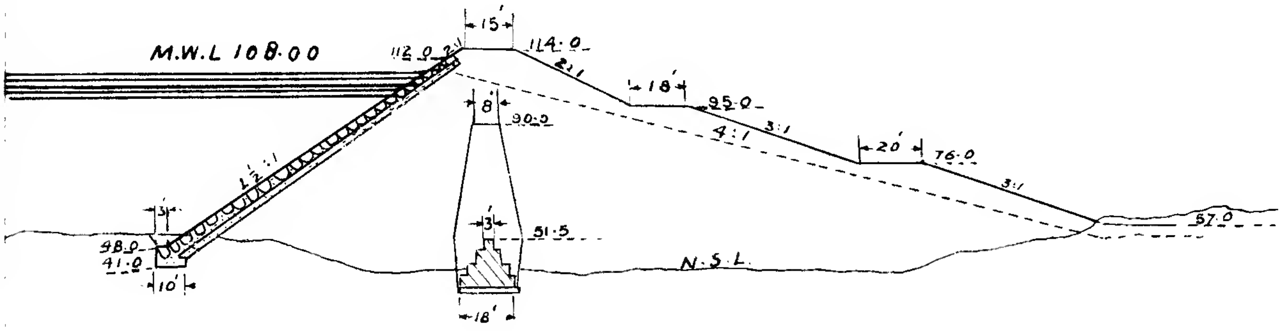
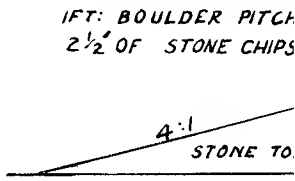
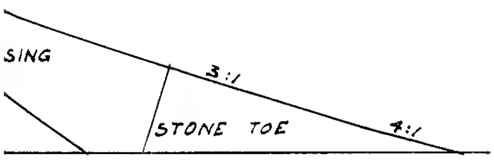
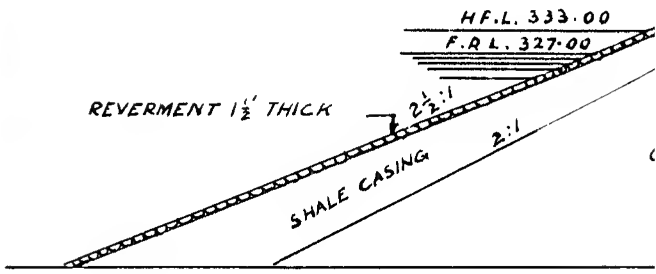
BYRAMANGALA DAM, MYSORE STATE



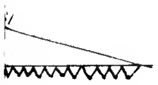


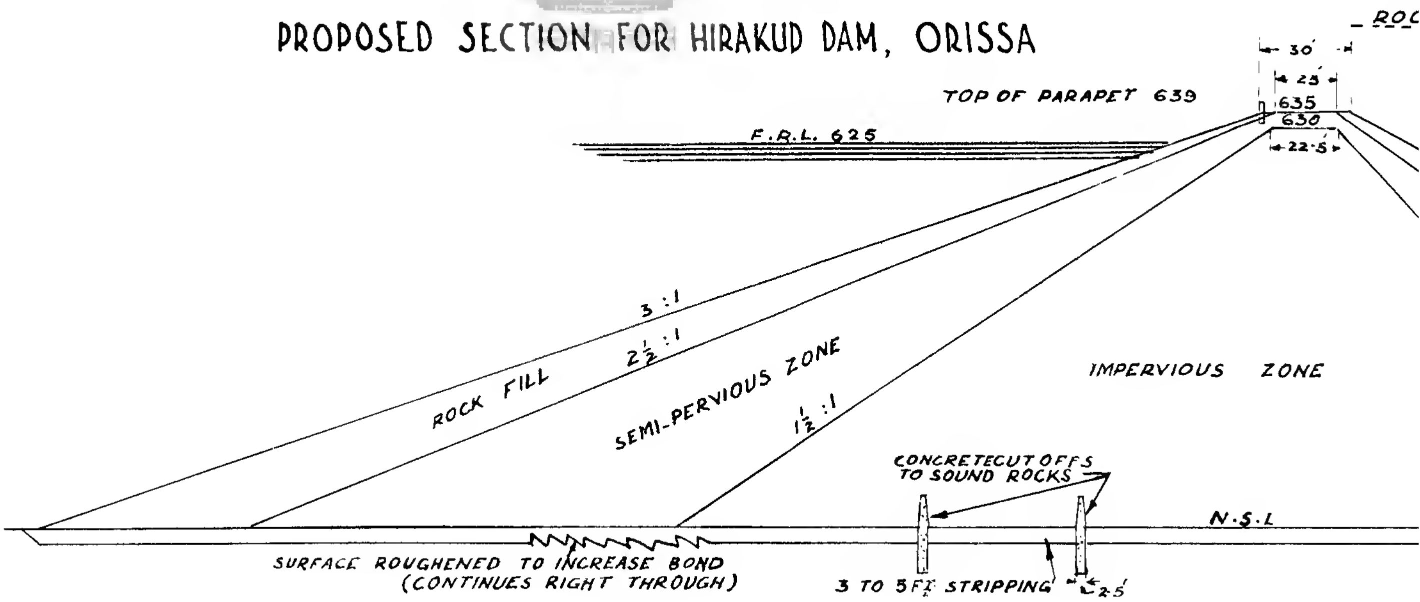
MOPA



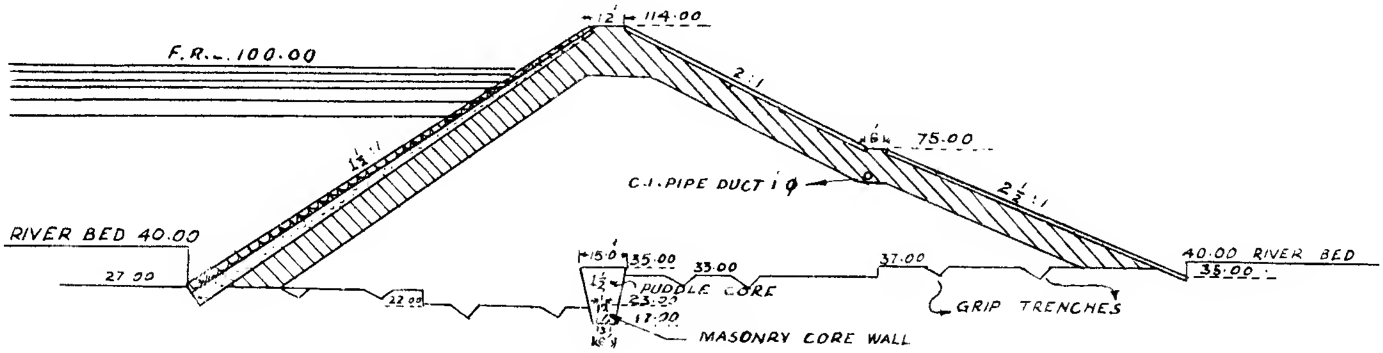


PROPOSED SECTION FOR HIRAKUD DAM, ORISSA

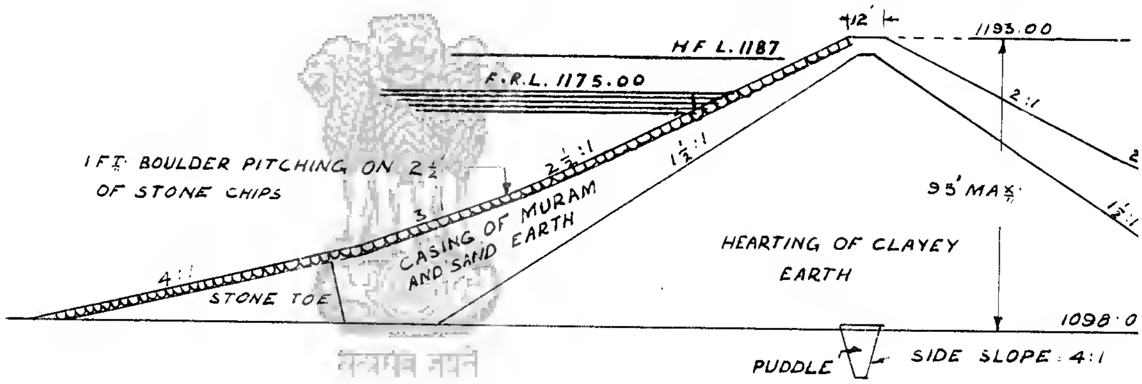




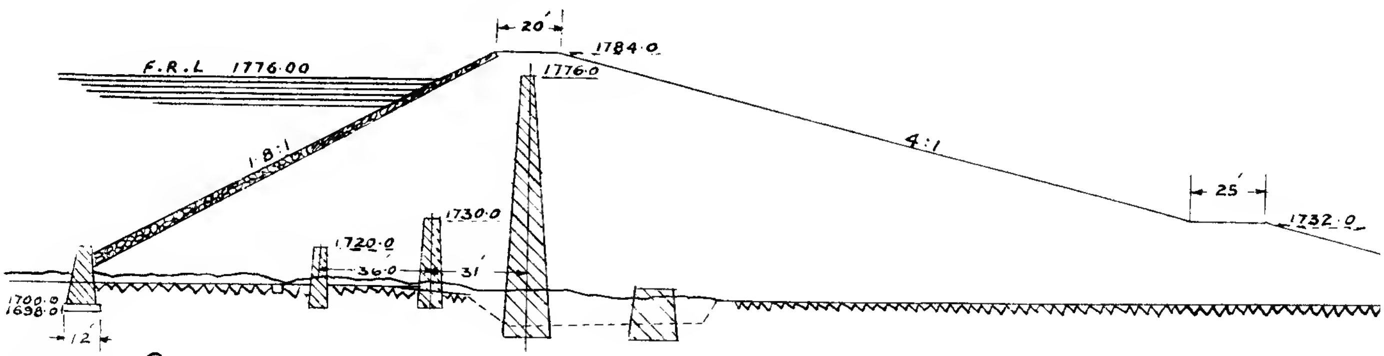
JOLAPURAM TANKBUND BANGANPALLE STATE



MANIARI DAM, CENTRAL PROVINCES



HIREBHASGAR DAM, MYSORE STATE



TRACED BY.... Sangam

COMPARED BY..... 5/6/1948

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ENCLOSURE 9

Statement of Comparative quantities of work to be done.

Items.		Project Report June 1947.	May 1948.	
1. Excavation for foundations	.. .. ..	2,00,00,000 Cft.		
(i) for concrete Dam—				
(a) Overburden ..	.. .. ..		96,56,000 Cft.	
(b) Hardrock ..	.. .. ..		81,79,000 Cft.	
			1,81,35,000 Cft.	
(ii) For Earth Dam—				
Sheet Piling ..	.. .. ..	10,000 Rft.		
Cut off Walls ..	.. .. ..		7,02,000 Cft.	
Excavation in overburden	Dam		2,50,00,000 Cft.	Most of this could be used in Earth Dam and so not provided in the original estimate.
	Right Dyke ..		2,23,00,000	
	Left Dyke ..		2,35,40,000	
			7,08,40,000	
2. Superstructure—				
Cement Concrete—1 : 3 : 6	.. .. ..	3,66,10,000 Cft.	3,84,01,660 Cft.	
Earth work—				
For Dam ..	.. ..	30,00,00,000 Cft.		
Dykes ..	.. ..	20,00,00,000 Cft.		
Stone pitching	.. ..	2,00,00,000 Cft.		
		52,00,00,000 Cft.		
Dam—				
Rock Fill ..	.. ..		7,58,00,000 Cft.	
Semi pervious fill	.. ..		10,90,00,000	
Impervious	.. ..		16,29,00,000	
Right Dyke—				
Rock fill ..	.. ..		2,20,00,000 Cft.	
Semi pervious fill	.. ..		2,84,60,000	
Impervious material ..	.. .. ..		3,24,60,000	
Left Dyke—				
Rock fill ..	.. ..		1,98,20,000 Cft.	
Semi pervious fill	.. ..		2,55,40,000	
Impervious fill	.. ..		3,66,80,000	
			51,26,60,000 Cft.	

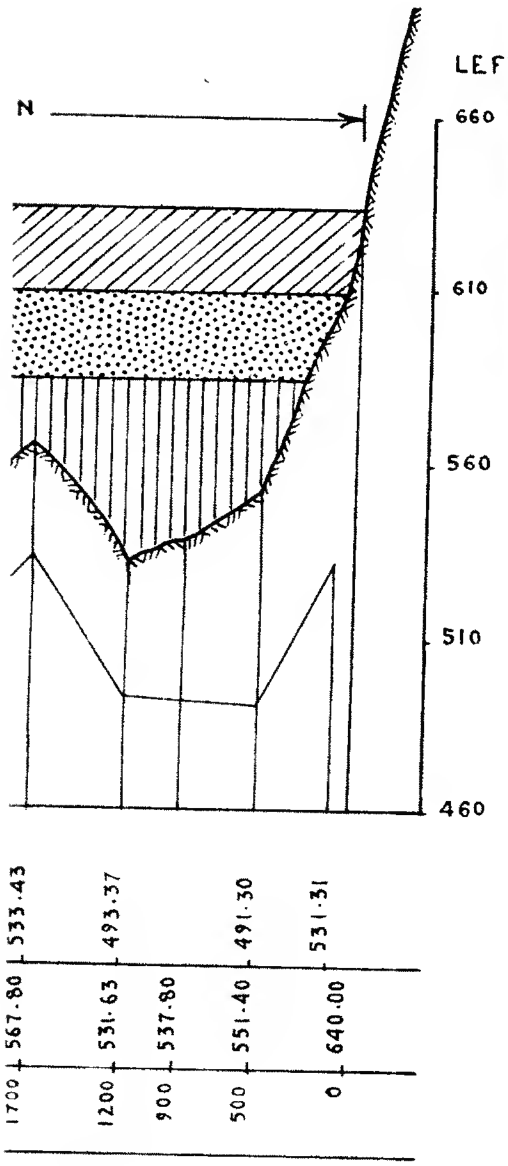
CONCRETING IN YEAR 1950-51 Enclosure No: 10 (116) 46

r: Per day as against 63,000 CFT:
in Narris Dam T.V.A.

EARTHWORK IN YEAR 1950-51

---1,45,850 CFT: Per day

---5,28,750 CFT: Per day



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PROJECT OFFICER,
MAHANADI PROJECT.

[OT]AL [CON]CRETE	EARTH PORTION							YEAR
	EXCAVATION IN STRIPPING	EXCAVATION IN ROCKS FOR CUT OFFS	CONCRETE IN CUT OFFS	FILTER DRAINS	ROCK FILL	SEMI-PERVIOUS FILL	IMPERVIOUS FILL	
CFT:	CFT:	CFT:	CFT:	CFT:	CFT:	CFT:	CFT:	
-	46,40,000	1,20,000	2,80,000	55,000	44,00,000	65,00,000	94,00,000	1948-49
[..]00,000	1,45,70,000	4,21,000	9,83,000	1,93,000	1,69,60,000	2,49,00,000	3,62,70,000	1949-50
[..],00,000	57,90,000	1,61,000	3,72,000	74,000	2,91,70,000	4,00,50,000	6,57,00,000	1950-51
[..]5,000	-	-	-	-	1,85,10,000	2,84,50,000	4,05,50,000	1951-52
[..]6,660	-	-	-	-	67,60,000	91,00,000	1,09,80,000	1752-53
[..]0,000	-	-	-	-	-	-	-	1953-54

MAXIMUM

50,000 (

Per da[y]

MAXIMUM

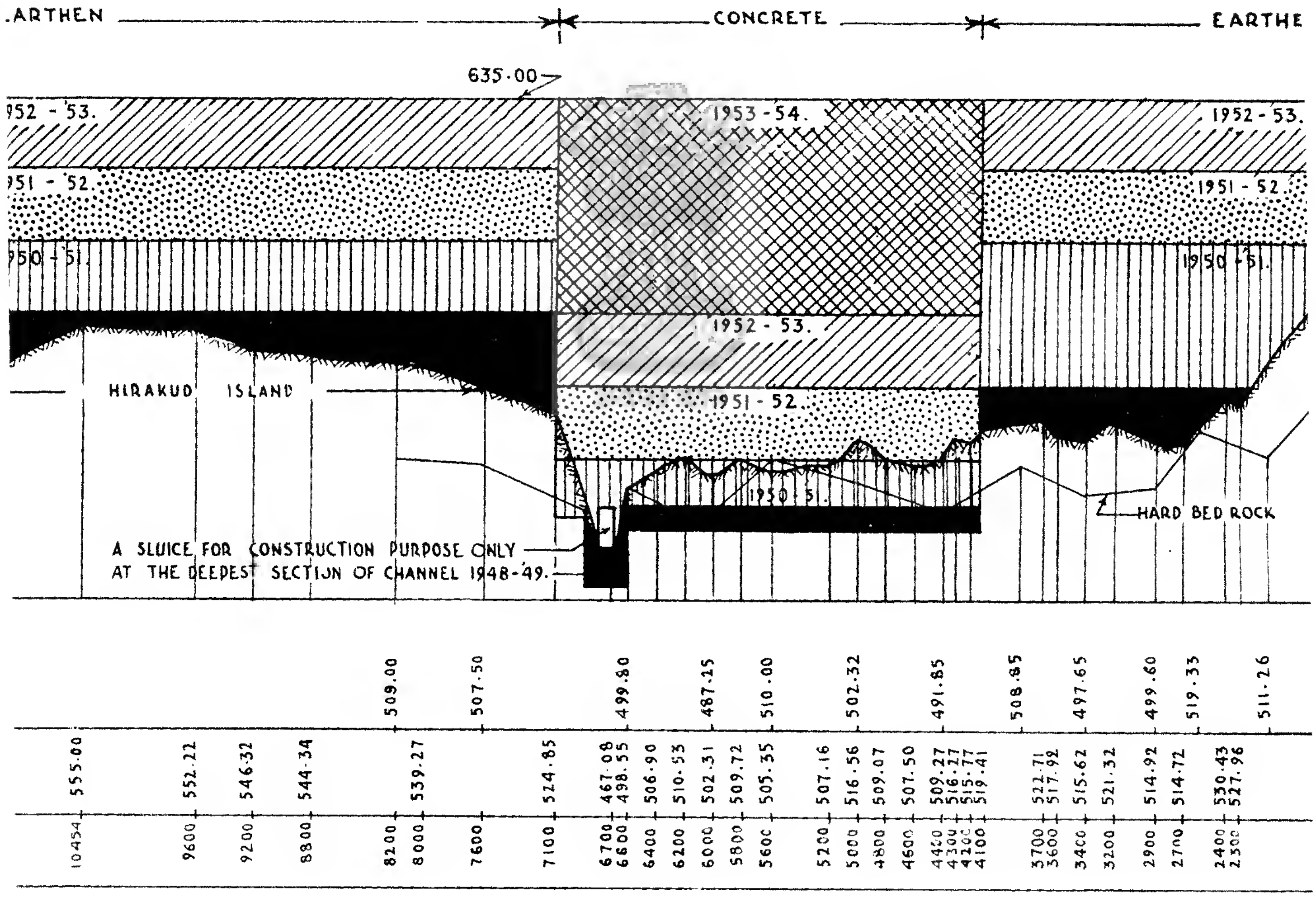
Rock fill

Earth fill

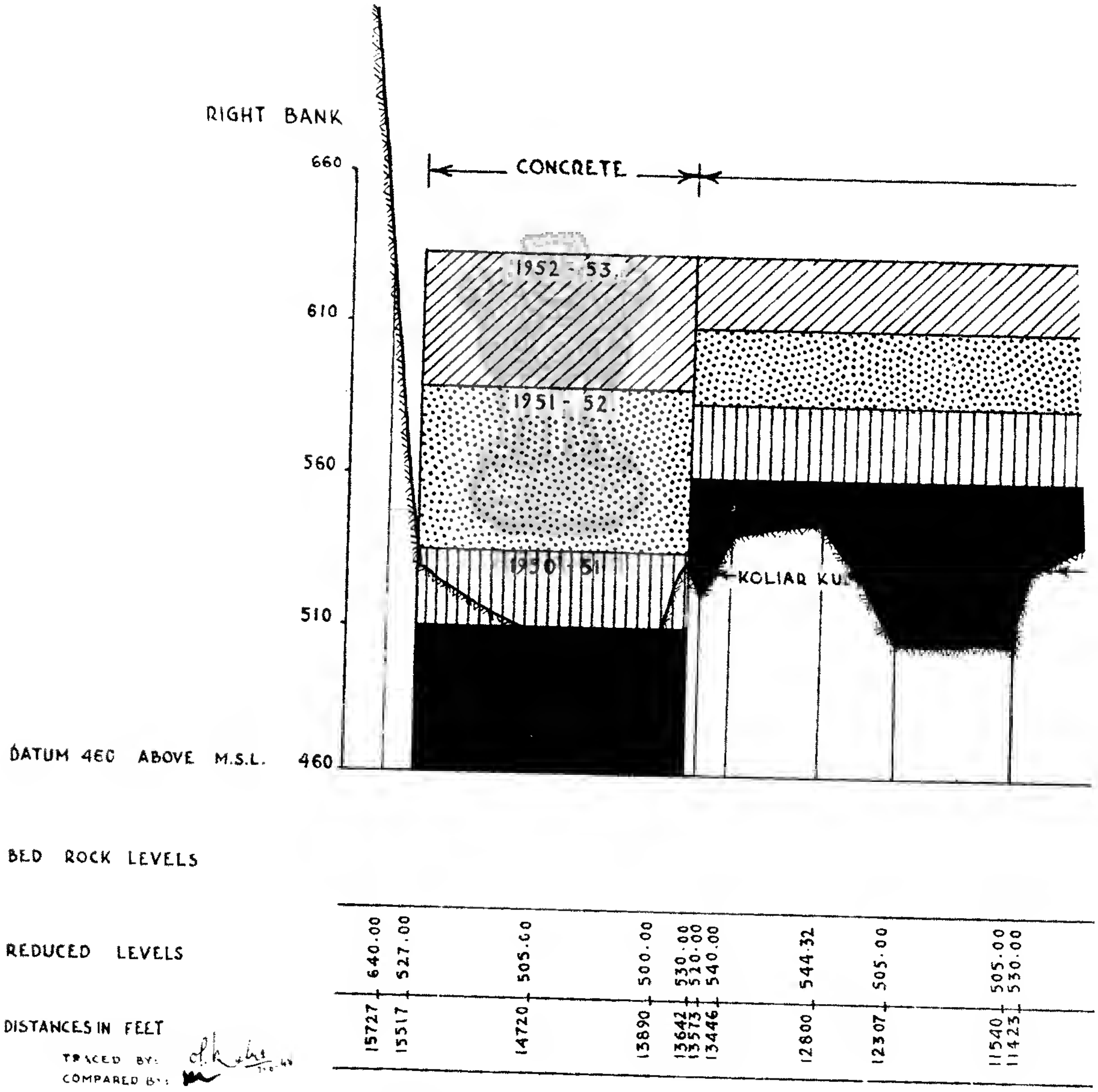
L. SECTION

ALONG CENTRE LINE OF HIRAKUD DAM

HOR: SCALE 1" = 1000' ~~~~ VER: SCALE 1" = 50'



YEAR	MASONARY FOR COFFER DAM	CONCRETE PORTION			
		POWER HOUSE SECT:		SLUICES SECTION	
		EXCAVATION IN ROCK	CONCRETE	EXCAVATION IN ROCK	CONCRETE
	CFT:	CFT:	CFT:	CFT:	CFT:
1948-49	364,500	81,20,000	-	-	-
1949-50	-	-	40,00,000	32,01,000	-
1950-51	-	-	45,00,000	-	55,00,000
1951-52	-	-	55,85,000	-	40,30,000
1952-53	-	-	26,40,660	-	48,46,000
1953-54	-	-	-	-	73,00,000



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ENCLOSURE 11

Statement showing the rate of contribution and water rate per acre in the sanctioned Projects in the State of Mysore

Serial No.	Name.	Authority.	Water rate per acre.	Contribution per acre.	Rainfall.
					Inches.
1	Irwin Canal Works	G. O. No. 1365-89/KSS. 4634-58, dated 23-2-1932.	1st year Rs. 4. 2nd year Rs. 6. 3rd year Rs. 8. 4th, 5th & 6th years Rs. 10.	Varying from Rs. 100 to 150 depending on the nature of soil in instalments spread over 12 years.	25
2	Construction of a reservoir across the Kumudvati river near Anjanapur, Shikaripur Taluk.	R. 1106-9/L. R. 253/37-6, dated 31-8-1938.	1st year Rs. 4. 2nd year Rs. 5. 3rd year Rs. 6. 4th year Rs. 7. 5th year Rs. 8.	Rs. 50 per acre in 12 instalments.	35 to 40
3	Construction of a reservoir across the Shimsha near Maroonahalli, Kunigal Tk.	P. W. 2387-91/S, dated 29-1-1941.	Rs. 6 per acre and Rs. 2 per acre for existing wet.	Rs. 175 per acre.	15
4	Construction of a reservoir across the river Byarmangala, Closepet Taluk.	P. W. 4106-10/S, dated 12-6-1939.	Rs. 6-8-0.	Rs. 100 in 10 instalments.	25
5	Alahally tank, Kankanhalli Taluk ..	P. W. 3192-7/S, dated 6-4-1939.	Rs. 6-0-0.	Rs. 100.	25
6	Construction of a new tank across Jinigehalla at Sangenahalli in Jagalur Taluk.	P. W. 4726-29/ Irgn./45-66, dated 5-1-46.	Rs. 5-8-0.	Rs. 100.	15
7	Construction of a new tank across the Shyagalihalli near Muthukadur village, Holalkere Taluk.	P. W. 2325-27, dated 28-10-1944.	Rs. 5-8-0 in addn. to existing assessment.	Rs. 100 in 10 instalments.	15
8	Construction of a new tank across Sokkehalla near Gadimakunte in Jagalur Taluk.	P. W. 6528-31, dated 24-3-1944.	Rs. 5-8-0.	Rs. 100.	15
9	Construction of a new tank across the Chickahagari near Thuppadahalli, village, Jagalur Taluk.	P. W. 6524-27, dated 24-3-1944.	Rs. 5-8-0.	Rs. 100.	15
10	Construction of a reservoir aross the river Kanva, Channapatna Taluk.	P. W. 998-1000/S, dated 16-9-1940.	Rs. 5-8-0. Rs. 8-0-0.	Rs. 100. Rs. 125.	25

ENCLOSURE 12.

Note on land compensation under Krishnarajasagar Reservoir.

SUBMERSION

The site selected for the Krishnarajasagar Reservoir across the River Cauvery in Mysore State has the advantage of least extent of sumbersion of valuable lands as compared with the several sites investigated before starting construction. In spite of this, rich and fertile irrigated tracts commanded by 6 irrigation channels in full and in part under 6 more channels have come under submersion, besides the valleys covered with cocoanut and plantain garden with patches of sugar-cane. The submerged area had plenty of grazing ground for cattle and also dry cultivation.

The reservoir is built for a storage of 124 feet depth and the construction started in the year 1911 was completed in 1931. It is therefore evident that the acquisition of lands which come under submersion for the final storage of 124 feet was not necessary in full to start with but could be taken up as and when found necessary. It was therefore decided to acquire in 3 stages—namely up to 80 feet depth in the first instance, up to 106 subsequently and 124 feet finally. The following table gives the areas submerged and the number of villages that had to be shifted in different stages.

Items	Number of villages affected.	Extent of lands submerged in acres			
		Dry.	Wet and Garden.	Village site Kharab etc.	Total.
(1) Area submerged up to 80′ depth of storage.	11	4,656	5,320	5,424	15,400
(2) Area submerged between 80 and 106 feet.	8	3,507	1,442	651	5,600
(3) Area submerged between 106 and 124 feet	6	5,760	2,848	2,392	11,000
Total ..	25	13,923	9,610	8,467	32,000

In addition to the above, villages numbering 25 had to be rebuilt due to submersion and nearness to the water spread. This affected nearly a population of about 15,000 including one town of 3,000 people.

MODE OF ACQUISITION.

(A) *Lands*--

In acquiring these lands and resettling the population on new lands, a novel procedure has been adopted in this reservoir with a view to cause as little hardship as possible to the drowned-out population. Experience on other works has shown that paying money compensation to owners of lands, with Government taking no steps to resettle them, will, in the majority of cases end in reducing the people to the condition of day labourers, because the displaced population will not be able, left to themselves, get other lands for purpose of cultivation and will not have an opportunity of resettling in the same neighbourhood. For these reasons, the designers of the project aimed at providing the displaced ryots with lands in exchange as far as possible supplemented where necessary by money compensation. This was no easy job as no wet land existed in possession of Government. Therefore the possibilities of opening new channels in the immediate neighbourhood were investigated and

happily the attempt was successful. Three new channels were opened out, one above the reservoir and two directly from the reservoir *viz.*—

(1) Chamaraj Right Bank Channel irrigating 11,000 acres.

(2) 2 Irrigationchannels taking off from the reservoir at 40 level one on either bank commanding a total extent of 5,000 acres.

Seven existing channels in the Cauvery valley were improved and extended to irrigate approximately 11,700 acres as detailed below :—

Above the Reservoir :

1. Mandagere Right Bank Channel	.. 5,000 acres.
2. Hemagiri Channel	.. 700 acres.

Below the Reservoir :

3. Chickdevaroy Sagar Channel	.. } 6,000 acres.
4. New Branch Channel at 1/65 of Chickdevaroy Sagar Channel	..
5. Baburayanakoppal sluice channel of Chickdevaroy Sagar Channel	..
6. Branch channel at 8 & 9/18 of Madhavamantry Channel	..
7. Sthothramanya Branch of Madhavamantry Channel	..
Total new wet area developed	.. 27,700 acres.

With a view to getting possession of Government wet lands under irrigable extents of the above-mentioned channels for award to the displaced ryots of the reservoir, holders of lands having an extent of 3 acres and above which got converted into wet by the above projects were asked to give up not less than one-third of their holding to Government in lieu of money contribution due from them to Government, because of the cost of the canal projects newly undertaken and were exempted from payment of cash compensation on the other one third under their holding and were called upon to pay cash contribution only on the remaining one third extent. It was also laid down in the case of recalcitrant ryots who would not surrender to Government one third of their holding as laid down above, that it may be compulsorily acquired under the Land Acquisition Regulation for the purpose of resettling the displaced population.

The area brought by these means, together with the Government waste, gave sufficient area to complete the first stage acquisition namely 80 feet depth of storage and the balance of land available met the demand up to 106 level, still leaving about 1,250 acres for award in exchange for the final stage of 124/. For dry lands submerged, Government waste was given in exchange.

In the system of compensation of land for land, the following concessions were also shown to the expropriated ryots :—

(1) For preparing the lands for cultivation, a cash compensation of Rs. 15 to 20 per acre of wet land and Rs. 5 to 10 for dry land was also paid as preparation charges.

(2) The submerged lands varied in quality and by long use were superior to the lands given in exchange. A drowned-out wet land in some cases enjoyed summer supply while the new land did not carry that right. Therefore after assessing the merits of each land regarding the quality and hot weather facilities, a greater extent of new land was given for each area of submerged land. This varied from $1\frac{1}{4}$ to 2 acres of new land to 1 acre of submerged land.

(3) The hickals for new lands passing through more than one village were not opened out at Government expense.

(4) Whenever a dry land which could be made irrigable was given in exchange for a a wet or garden land submerged, the assessment was totally or partially remitted for a term of years according to circumstancs of each case.

(5) Indebted ryots were assisted to pay off their debts by granting loans in all deserving cases, the loan being repayable in convenient instalments and in case of default to be recovered as arrears of land revenue.

(B) *Villages*—

As regards villages, each house was assessed and valued and the owner paid half the value in cash and was permitted to take all the materials that could be had from the submerged houses. In addition, timber was sold at half the prevailing market rates, the loss on this account being shared equally by the reservoir works and the Forest Department. For building the houses, suitable sites for new villages was formed and given free. In addition, the Government at their own expense formed roads, drains, wells, paid cost of acquisition of land for sites and constructed a school or a chavadi and also a temple.

The establishment for acquisition consisted of a Senior Assistant Commissioner with necessary staff. He was aided by an Assistant Superintendent of Surveys and Settlement with measurers (Surveyors). The Engineering Department fixed up boundary stones at the required contours for acquisition and the land Surveyors measured the extents coming under submersion in each survey number for being acquired.

CONCLUSION.

By adopting the above methods, the hardships to the dispossessed ryots under the reservoir were minimised to a very great extent. This system, though not free from difficulties and short comings, has proved beneficial and people have found lands and houses though at some distance from their old habitations.

From the Government standpoint, the adoption of this system has been found to be very economical. If cash compensation had been paid in the usual way it would have cost to Government :—

(1) For acquiring 9,600 acres of wet land at Rs. 400 per acre	Rs. 38,44,000
(2) For acquiring 13,923 acres of dry land at Rs. 60 per acre	Rs. 8,38,380
Total ..	Rs. 46,82,380

As against this, Government have spent in opening out these channels Rs. 27 lakhs only or resulting in a savings of nearly 20 lakhs in original expenditure. Payment of cash compensation would have resulted in the loss of revenue to the State annually from submerged lands. But by opening these channels and awarding Government waste lands, this revenue is also got back to the State. In addition, it has also increased the wealth of the country and has conferred other direct and indirect benefits of irrigation projects. So it is seen that in more ways than one, the system adopted in this reservoir for settlement of drowned out population is advantageous both to the State and to the people. With the experience gained, it is expected that it is possible to reduce the hardship to the ryots still further by improving any short comings of the system.

Statement showing the extent of wet and garden lands submerged upto plus 124 contour of Krishnaraja Sagar water spread under the several channels that existed prior to 1910.

Serial No.	Name of River.	Name of channel.	Area submerged in acres and guntas.	Remarks.
		Fully Submerged Channels.		
1	Cauvery	Thippur	1757-2	
2	Hemavathy	Kallahally	1377-34	
3		Kannambady	1486-17	
4	Lakshmanáthirtha	Anandur	1551-12	
5		Manchihally	473-29	
6		Ayarahally	213-31	
		Partially Submerged Channels		
7	Cauvery	Mirle series	734-2	
8		Ramasamudram	1282-29	
9	Lakshmanathirtha	Siriyur	56-2	
10	—	Hussainpur	182-28	
		Tank and Valley irrigation	403-36	
			9519-22 or say 9520 acres	
	Add area coming under submersion in the channels opened out after 1910.			
1	Cauvery	Chamaraja Right Bank	178-30	
2	Hemavathy	Mandagere extension	150-5	
3	Hemavathy	Hemagiri	81-19	
			410-14	
		Grand Total ..	9929-36 or say 9930 acres	

Statement showing the new channels opened & extensions effected above & below Krishnaraja-sagar reservoir for settling the expropriated ryots.

Serial No.	Name of river.	Name of channel newly opened or extended.	Area newly brought under cultivation (as per statistics of 1945-46).
		'A' Above the reservoir.	
1	Cauvery	Chamaraja Right Bank	10566·0 New Chl.
2	Hemavathy	Mandagere Right Bank Extension	4987·0
3	Hemavathy	Hemagiri extension	632·0
		'B' From the reservoir.	
4		Right Bank Low Level channel	3241·0
5		Left Bank Low Level channel	1461·0
		'C' Below the reservoir.	
6	Cauvery	Chikkadevaray sagar new channel 1 from 1/65 main Baburayanakoppal branch of Chikkadevaray sagar.	6000·0 (items 6 and 7)
7	Cauvery	Branch channel at 8 & 9/18 of Madhavamantry main Sthothramanya branch of Madhavamantry main.	
		Grand Total ..	26887 acres or 26900 acres.

Statement showing the villages submerged below plus 124 contour of Krishnaraja Sagar water spread and new villages formed to settle them.

Serial No.	Name of village submerged.	Village formed in their place.
1	Kannambady	Old village shifted and a new village by name Srirampur was also formed.
2	Chickairahalli	Old village shifted.
3	Sayappanahalli	Do.
4	Heraganahalli	Do.
5	Hosakote	Do.
6	Puvanahalli	Do.
7	Bukahalli	Do.
8	Varahanta Kallahalli ..	Do.
9	Adagur	Do.
10	Ambigarahalli	Do.
11	Sangapura	Do.
12	Degganhally	Do.
13	Yedatore (Town)	A new town by name Krishnarajanagar was formed.
14	Hosur	Old village shifted.
15	Kundur	Do.
16	Kallahally	Do.
17	Waddarhally	Do.
18	Harohally	Do.
19	Mulepetlu	Do.
20	Sagarkatte	Do.
21	Ramenahally	In addition to shifting the old village a new village of the same name was formed near Bolenahally along Yelwal-Krishnarajanagar Road.
22	Budihosakote	Old village shifted.
23	Yedehally	Do.
24	Anandur	In addition to shifting the village a new village of the same name near Belagula pumping station was formed.
25	Unduvady	The old village was shifted and another new village of the same name formed near Krishnarajasagar Railway Station.

G. O. No. 6381-6224—L.R. 480-12·1, DATED THE 5TH MAY 1913

Order

The construction of the new Cauvery Reservoir at Kannambadi involves the submersion of the about 5,000 acres of wet land and 4,656 acres of dry land situated in forty-eight villages, of which eight villages will be more or less completely submerged and also the displacement of a population of about 5,000 souls.

2. The question of acquiring these lands by payment of compensation and of resettling the population displaced on new land has been engaging the anxious attention of Government for some time past. On account of the magnitude of the work the problem of land acquisition in this case offers certain peculiar difficulties, necessitating the adoption of measures of an exceptional character.

3. In their Proceedings No. 317—20—L. R. 173—12—2—, dated 18th July 1912—,* Government appointed Mr. L. Krishna Rao, as Special Acquisition Officer to investigate the question on the spot and suggest the best means of protecting the interests of the affected people. This officer, in conjunction with the Superintending Engineer, Mr. B. Subba Rao, has submitted tentative proposals which are generally concurred in by the Deputy Commissioner and the Chief Engineer. The proposals are now before Government with the observations of the Revenue Commissioner.

4. The simplest solution of the question is to acquire the lands under the Land Acquisition Regulation from the private owners after paying them compensation in the usual way, and this method is favoured by the Revenue Commissioner. But the displaced population will in that case be unable if left to themselves, to get other land for purposes of cultivation and will not have an opportunity of resettling as agriculturists in the same neighbourhood. Experience elsewhere has shown that if Government content themselves with paying money compensation to owner of land and no steps are taken to resettle them, it will, in the great majority of cases, end in reducing the people to the condition of day labourers.

5. For these reasons, it has been the aim of the officers who prepared the project to attempt to provide the displaced raiyats with lands in exchange, as far as possible, supplemented, where necessary, by money compensation. In such cases, the displaced population is usually settled on land brought under irrigation by the construction of the reservoir. But happily in the present case, there exist in the immediate neighbourhood facilities for carrying out three channel extension projects which might be taken advantage of for the present purposes. The Alalkatte, Hemagiri and the Mahadagiri channel projects roughly estimated to cost about 25 lakhs, were prepared some years before the Khanambadi project was thought of. The Acquisition Officers' report shows that with certain additions and alterations these projects can now be utilised.

6. The amount of compensation for acquiring land included in the sanctioned estimate for the first stage of the project is about 10 lakhs. This estimate was based on the figures furnished some years ago by the late Revenue Commissioner, Mr. A. Rangaswami Iyengar. It is pointed out that if money compensation alone is paid in the usual way, the estimate of 10 lakhs would be considerably exceeded. If land compensation is attempted, it is reported that Government may have to spend about 13 lakhs more. But the additional 13 lakhs which would enable Government to carry out three important channel extensions would be a remunerative outlay in itself. Although these projects were ready some years ago and their construction was repeatedly urged in the Representative Assembly, they could not be sanctioned as there was uncertainty about the water supply. Now that the reservoir will protect

* Serial No. 1 *Supra.*

all irrigated area below it, the extension of the upper channels can be carried out without detriment to irrigation in the lower reaches.

7. Worked with proper safeguards, Government feel assured that the proposal to give land in exchange will be more economical from the point of view of the State, and that by adopting it, Government will be consulting the permanent interests of the displaced population.

8. The main outlines of the scheme which is based chiefly on the proposals of the Land Acquisition Officer prepared in consultation with the Superintending and Chief Engineers, are as follows :—

(1) As far as possible compensation shall take the form of land to be given in exchange for the land taken up for the reservoir.

(2) For this purpose all available cultivable Government land in the neighbourhood shall be utilised when it is expected that the holders of occupied lands under the Alalkatte, Hemagiri and Mahadagiri channels could be induced to part with portions of their holdings, in consideration of provision being made for irrigation that a large number of cultivators have agreed to such an arrangement and that the displaced cultivators are willing to remove to the new lands proposed to be made available.

(3) Before the projects are finally sanctioned the rate of contribution to be paid by the owners of occupied lands, which will be benefited by the projected canal works and the conditions on which they will agree to give up the lands should be definitely settled and embodied in the mutchalikas executed by them.

(4) Where land taken is superior in quality to that given in exchange, a money compensation to make up for the difference in value shall be given.

(5) Where the owners of lands that are to be taken up have only a limited interest in them, an agreement shall be entered into with the creditors or other persons concerned for an exchange of land on the above lines ; failing which money compensation will be awarded for the whole land under the provisions of the Land Acquisition Regulation. In deserving cases, loans may also be given to the indebted raiyats on the security of the land given in exchange to enable them to pay off the creditors and convey a free title to the Government the loan to be repayable in convenient instalments and to be recoverable, in default of payment, as an arrear of land revenue.

(7) A supplementary money grant not exceeding a fixed scale may also be made to the raiyats where land given in exchange is new and required some initial outlay to render it fit for purposes of cultivation.

(8) Where the land taken up is wet or garden and the land to be given in exchange is dry, but which can be made irrigable, the wet assessment to be imposed thereon may be totally or partially remitted according to the circumstances of each case for a term of years.

(9) Where for any reason, it is not found practicable to settle by private negotiation, the grant of land in exchange for land, a money compensation shall be fixed and awarded under the usual acquisition proceedings.

(10) The expropriated owners of the submerged lands who consent to receive lands in exchange should be required to execute mutchalikas to that effect and in

case there are subordinate interests in the land, similar mutchalikas should be taken from the persons concerned. The form of the mutchalika should be settled in consultation with the Government Advocate and submitted for the approval of Government.

(11) As soon as the expropriated owners have agreed to receive other lands in exchange possession should be taken on behalf of Government of the lands which will be submerged, and if the lands to be given in return are immediately available, the exchange should be given effect to at once. In case it is likely to take some time to provide the land, the expropriated owners may be allowed to continue in possession of the land taken up on behalf of Government until it is submerged, or lands in exchange have been given. In exceptional cases where some time is likely to elapse between the submersion of the land and the grant of other lands in exchange, a reasonable amount not exceeding the net profit on the land may, with the sanction of the Deputy Commissioner, be given to the expropriated owners.

(12) The raiyats of Government and Inam Villages, who have to abandon their houses in the Reservoir bed and take up lands in exchange elsewhere, may be allowed in addition to the compensation free grants of timber and other building materials on the same scale as is allowed to agriculturists, whose houses have been destroyed by fire.

9. Government are pleased to approve of the general lines of the scheme of settlement and compensation set forth above. The details of the scheme may be worked out, if need be, in convenient instalments and submitted through the Revenue Commissioner for the final orders of Government. Maps and statements should be submitted separately for each village taken up as well as for the corresponding area in which it is proposed to settle the displaced population.

Government desire that, in cases of doubt or difficulty, the Deputy Commissioner of the Mysore District, the Superintending Engineer in charge of the work and the Special Acquisition Officer should form themselves into Committee and submit their recommendations to Government in the Public Works Department through the Revenue Commissioner.

10. The Chief Engineer is requested to submit rough plans and estimates, for all the canal extension projects proposed, within three months and detailed plans and estimates within six months.

11. In para. 7 of his letter, the Deputy Commissioner recommends that a separate Revenue Sub Division be constituted of the area over which land acquisition operations extend and that the Special Acquisition Officer be invested with the powers of a Revenue Sub-Division Officer and given the services of two capable Deputy Amildars and four Shekdars under him. These proposals which are supported by the Revenue Commissioner are sanctioned.

12. Government are also pleased to direct that Rule 14 of the Rules under the Land Acquisition Regulation will not apply to the Special Acquisition Officer. Only such cases as involve an excess of 10 per cent. over the estimate prepared by him regarding the compensation payable, or where the amount of compensation to be paid in an individual case exceeds Rs. 2,000/-, may be referred to the Deputy Commissioner. If after further experience, it is found necessary to raise these limits, fresh proposals may be submitted.

13. A quarterly report should be submitted to Government in the Public Works Department by the Land Acquisition Officer through the Revenue Commissioner, showing the progress made in the settlement work, commencing from the quarter ending 30th June 1913.

14. Before concluding, Government desire to express their appreciation of the care and interest with which the Special Acquisition Officer, Mr. K. Krishna Rao, has dealt with the preliminary stages of this difficult question.

G. O. No. R. 7726-8-L. R. 337-13-5, DATED 30TH MARCH, 1914.

Order.

Scales for the grant of land compensation.—The lands likely to be submerged are proposed to be divided into five classes, *viz.* ; garden lands, wet lands of three qualities, *i.e.*, 1st, 2nd and 3rd and dry lands and for the purpose of effecting exchange, the following three alternative scales are suggested :—

A. SCALE.

1 acre of garden land acquired to be given 2 acres of fresh land with a bonus in cash at the rate of Rs. 50 per acre.

1 acre of wet land of the 1st quality to be given $1\frac{1}{2}$ acres of fresh land with a bonus in cash at the rate of Rs. 30 per acre.

1 acre of wet land of the 2nd quality to be given $1\frac{1}{3}$ acre of fresh land with a bonus in cash at the rate of Rs. 25 per acre.

1 acre of wet land of the 3rd quality to be given $1\frac{1}{4}$ acres of fresh land with a bonus in cash at the rate of Rs. 20 per acre.

1 acre of dry land acquired to be given 1 acre of fresh land with a bonus in cash at the rate of Rs. 5 per acre.

B. SCALE.

1 acre of garden to be given $1\frac{1}{2}$ acres of fresh land with a bonus in cash at the rate of Rs. 100 per acre.

1 acre of wet land of 1st quality to given $1\frac{1}{3}$ acres of fresh land with a bonus in cash at the rate of Rs. 30 per acre.

1 acre of wet land of 2nd quality to be given $1\frac{1}{4}$ acres of fresh land with a bonus in cash at the rate of Rs. 50 per acre.

1 acre of wet land of 3rd quality to be given 1-1/5 acres of fresh land with a bonus in cash at the rate of Rs. 30 per acre.

1 acre of dry land to be given 1 acre of fresh land with a bonus in cash at the rate of Rs. 5 per acre.

C. SCALE.

1 acre of garden land to be given 1 acre of fresh land plus a bonus in cash at the rate of Rs. 150 per acre.

1 acre of wet land of 1st quality to be given 1 acre of fresh land plus a bonus in cash at the rate of Rs. 100 per acre.

1 acre of wet land of 2nd quality to be given 1 acre of fresh land plus a bonus in cash at the rate of Rs. 75 per acre.

1 acre of wet land of 3rd quality to be given 1 acre of fresh land plus a bonus in cash at the rate of Rs. 50 per acre.

1 acre of dry land to be given 1 acre of fresh land plus a bonus in cash at the rate of Rs. 5 per acre.

The Deputy Commissioner explains that the classification of lands into five classes referred to above applies only to lands which are to be acquired and which are already under cultivation and not to newly irrigated lands to be given in exchange and that, in the case of the latter, an understanding has been arrived at with the owners of the lands concerned to allow owners of gardens to make the first choice and after them, owners of first class wet lands and that the reminder will be available for distribution among the other displaced raiyats. It is proposed to treat lands granted in exchange as corresponding to the class of the land in lieu of which the exchange is permitted. It is reported that it is intended to encourage the people to accept the exchange according to scale A, so that as large an area of newly irrigated land as possible may be brought under cultivation immediately and payment in cash reduced to a minimum and that the majority of the raiyats have agreed to this scale being adopted as the basis of the exchange. It is also stated that benefit of scale C will be chiefly given to Inamdars to whom it may be necessary to give an equivalent extent of land on the original tenure. Government generally approve of the three scales.

2. The other recommendations of the Committee noted below are also approved :—

(1) Recovery of contribution payable by persons surrendering a portion of their holdings for the benefit of the expropriated raiyats in four annual instalments.

(2) Reductions of the contribution payable in cash by a sum not exceeding Rs.15 per acre on an average at the discretion of the Land Acquisition Officer in the case of lands requiring a cutting of two feet to make them irrigable by the new channels.

(3) Allowing owners of submerged lands to remove trees without payment.

(4) Remission of the full amount of water rate for one year or half the water rate for two years on the irrigable area retained by such of the land-holders as surrender a portion of their holdings for the benefit of the expropriated raiyats.

(5) Levy of water rate at the following progressive rates on lands given in exchange to the expropriated raiyats :—

No water rate for the 1st year.
$\frac{1}{4}$ water rate for the 2nd year.
$\frac{1}{2}$ water rate for the 3rd year.
$\frac{3}{4}$ water rate for the 4th year.
Full water rate from the 5th year.

(6) Calculation of the cash bonus upon the extent of land given in exchange and not on the extent actually submerged.

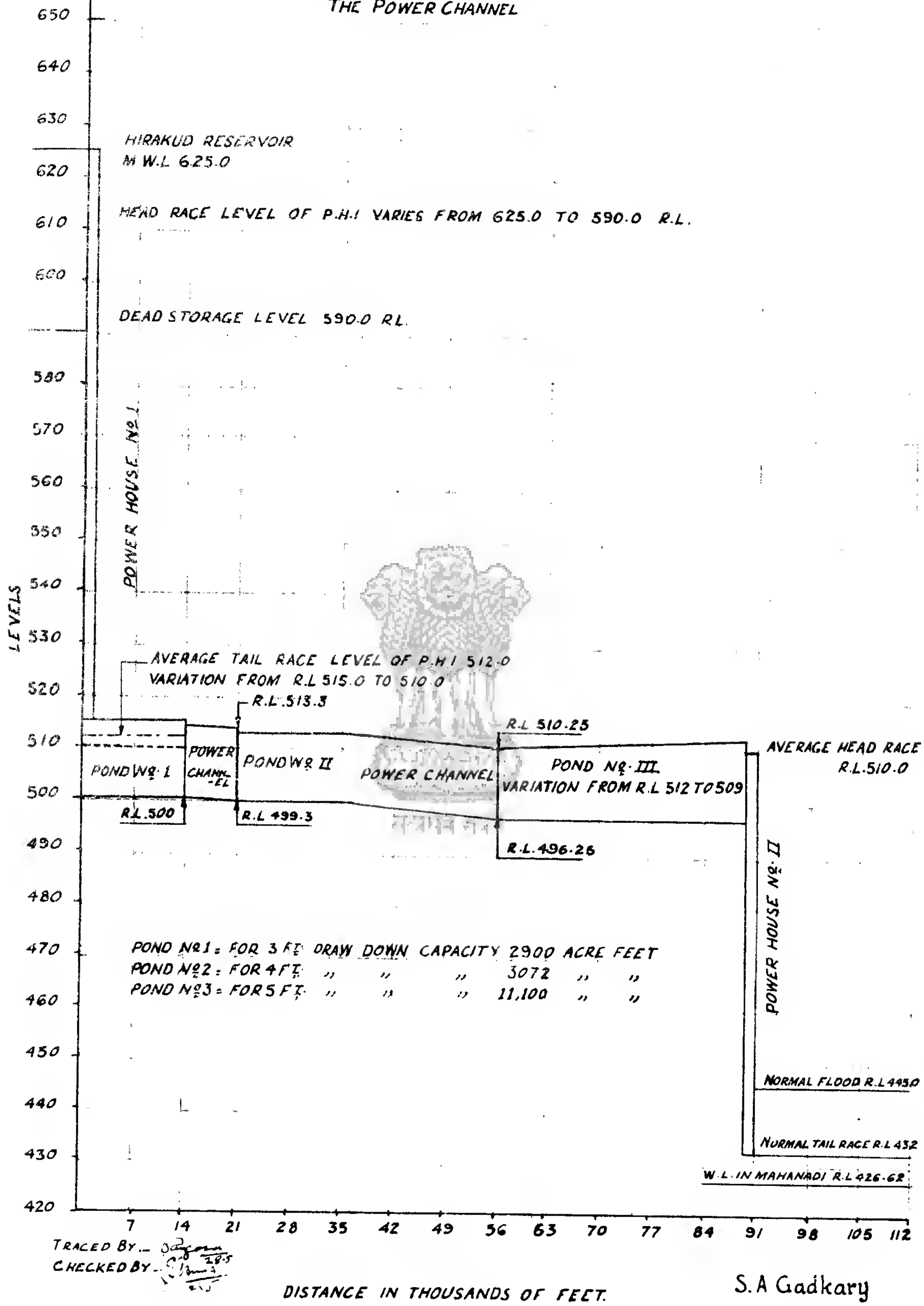
3. *Land Compensation Committee and Local Committees.*—As regards the formation of a separate Committee suggested in para. 6 of Government Order No. 2858-61-L.R. 295-13-2, dated the 27th September 1913, Sl. No. 6 *Supra.* it is brought to the notice that the existing Committee consisting of the Superintending Engineer, the Deputy Commissioner and Land Acquisition Officer have worked out all the details and that it is sufficient at the present stage to appoint local Committees of influential Land holders in each taluk to help the Land Acquisition Officer in carrying out the settlement. Government are pleased to approve of this suggestion.

MICWI&NC—1,000—17-7-48—GIPS

HIRAKUD DAM PROJECT

PICTORIAL REPRESENTATION OF THE POWER CHANNEL

FIG. 1



TRACED BY ...

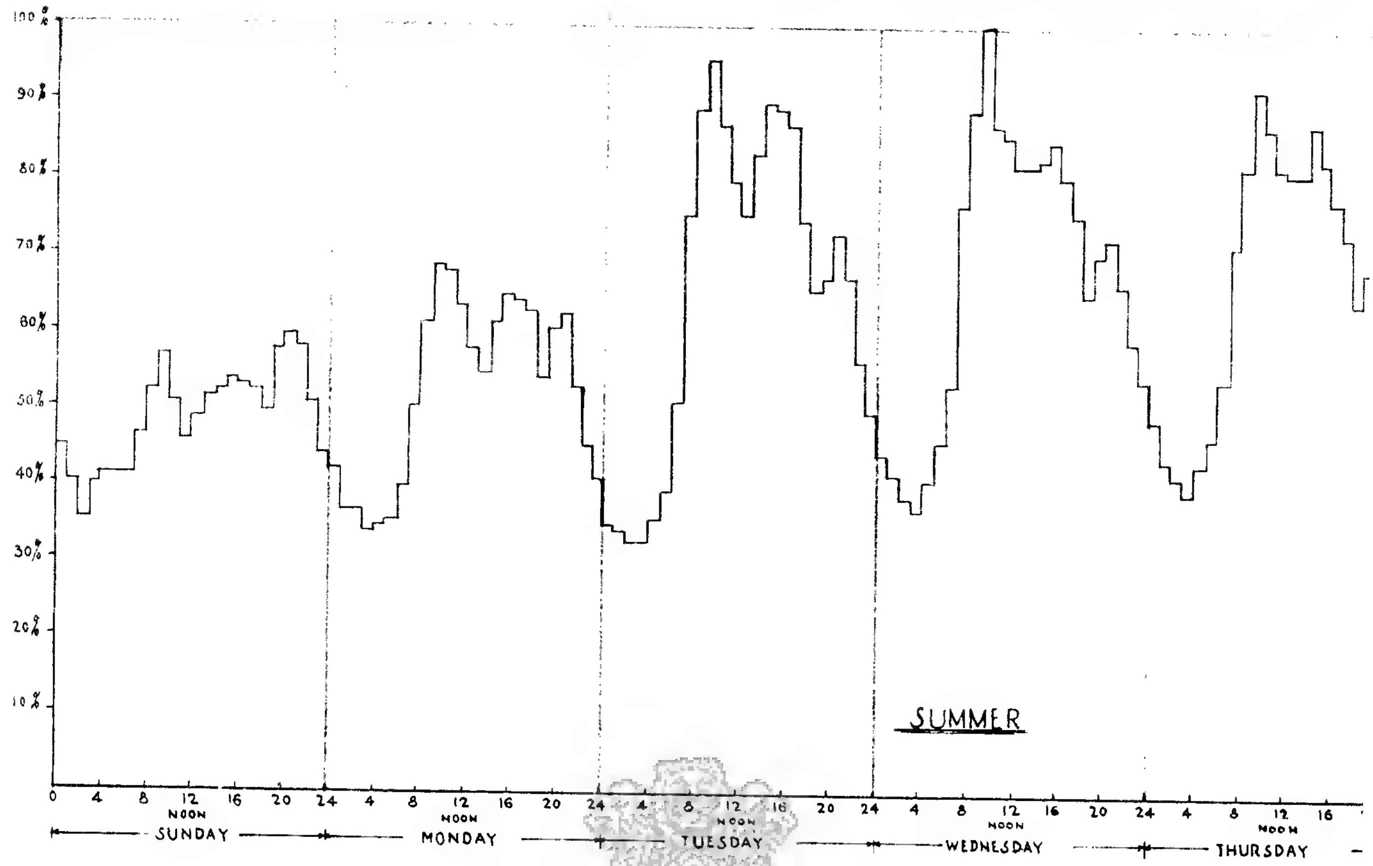
CHECKED BY ...

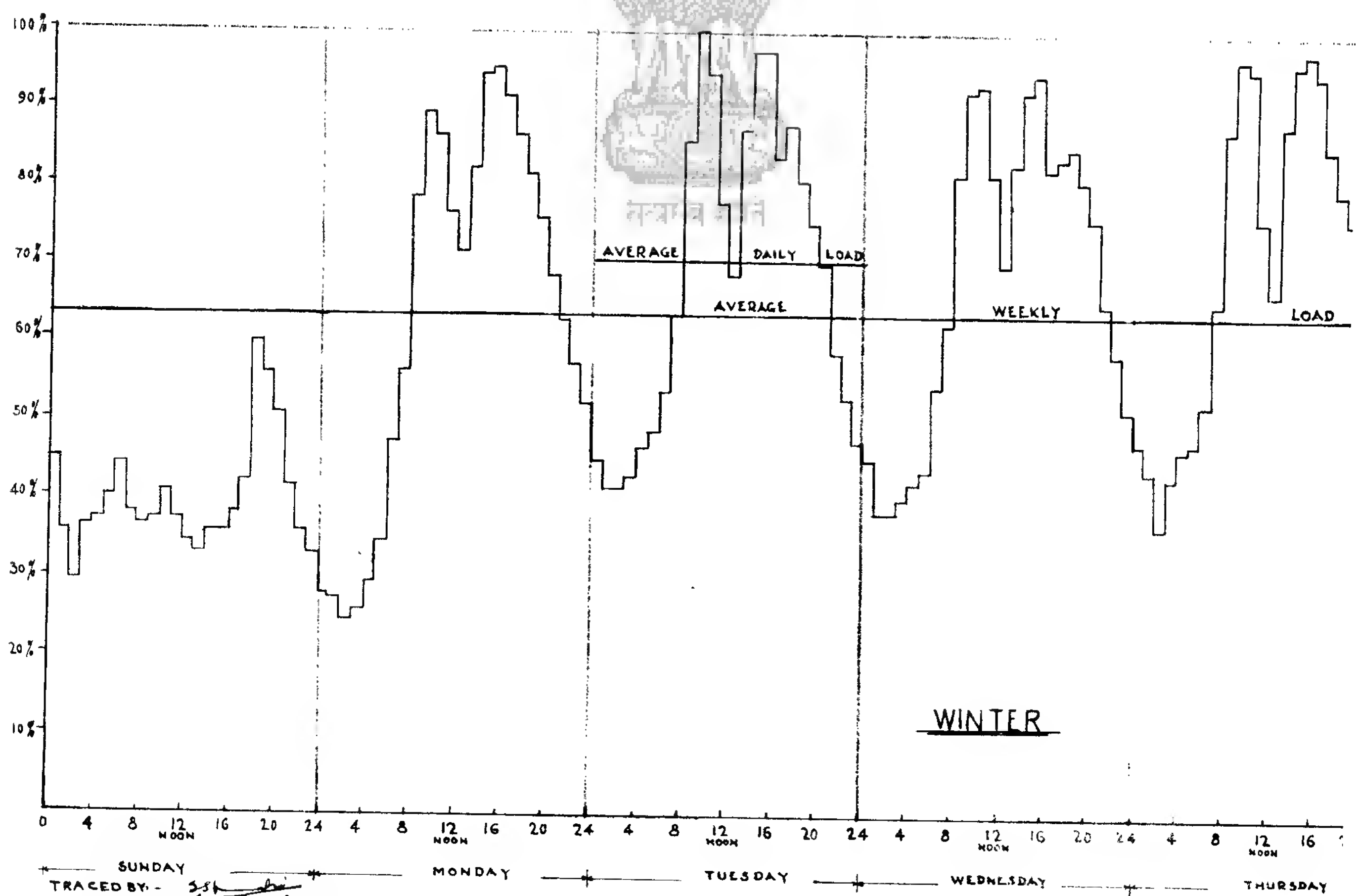
S. A Gadkary

Reg. No. 2822 H E'48-

Printed at the Survey of India Offices (H. L. O.)

TYPICAL DAILY & WEEKLY LOAD



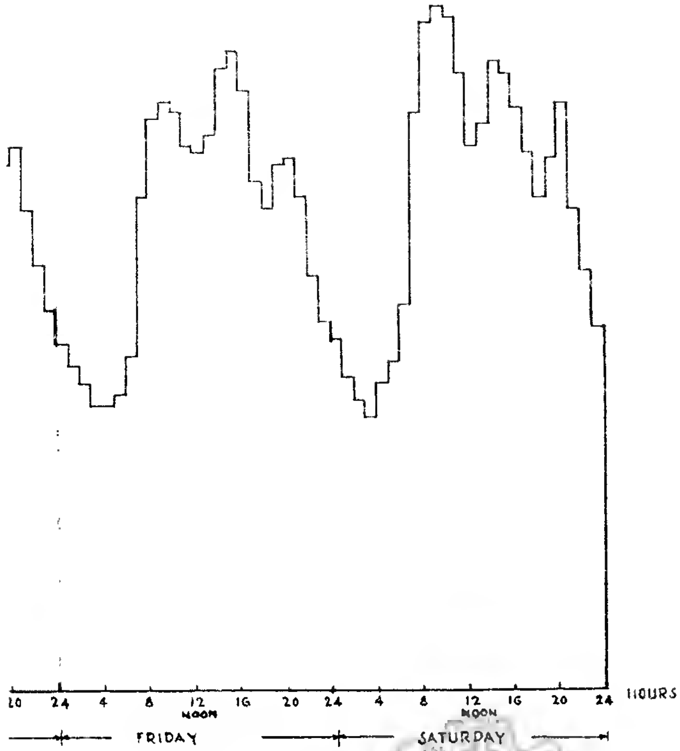


TRACED BY:- S.S.
COMPARED BY:- Laxman 6.5.1948

Reg. No. 2822 HE'48.

CURVES

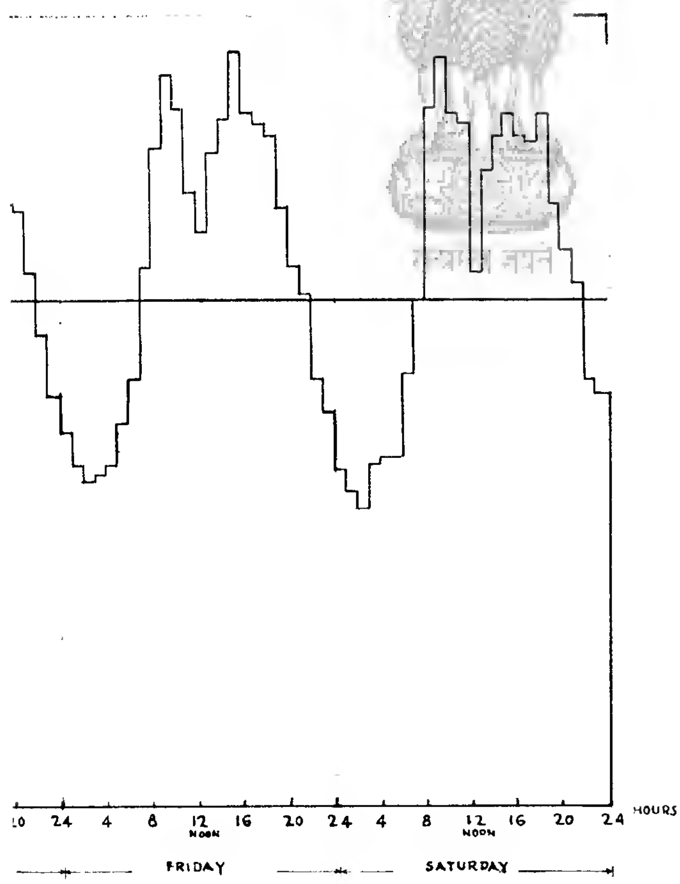
FIG. 2



DAILY LOAD FACTORS

DAY	LOAD FACTOR
SUNDAY	69·29 %
MONDAY	75·85 %
TUESDAY	67·95 %
WEDENSDAY	63·36 %
THURSDAY	71 60%
FRIDAY	75·19%
SATURDAY	71·82 %
FOR FULL WEEK	59·00 %

FIG. 3

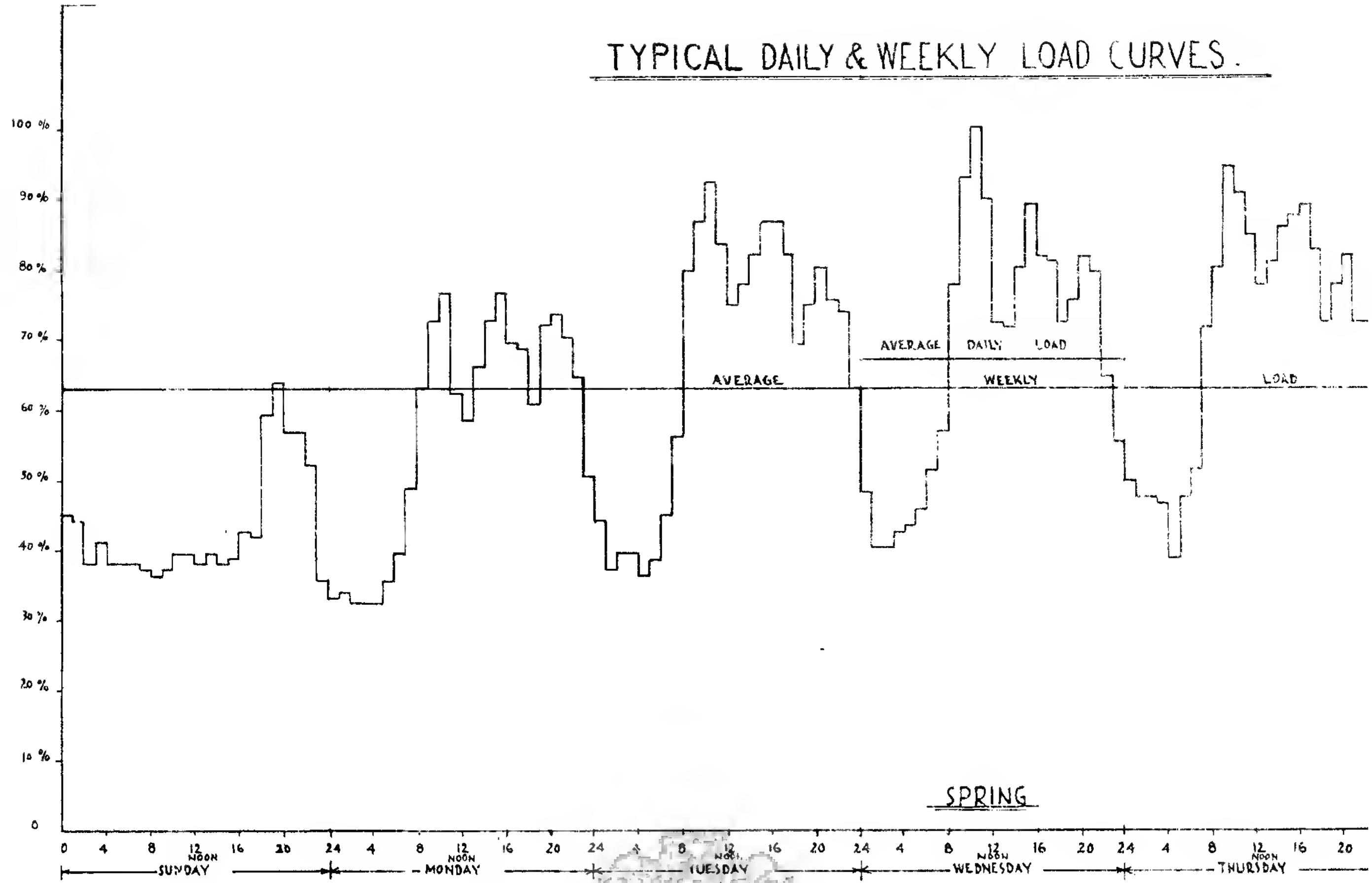


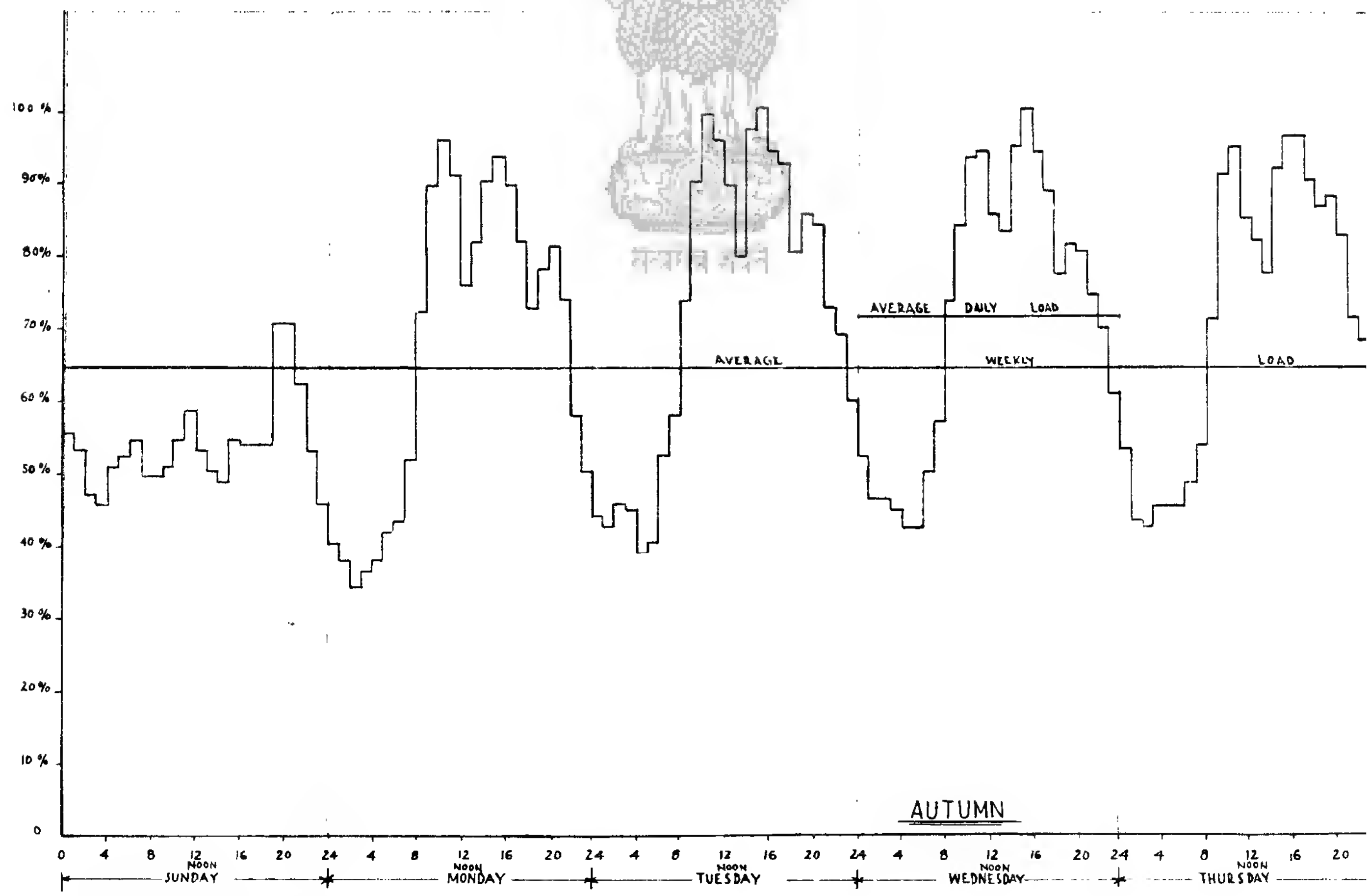
DAILY LOAD FACTORS

DAY	LOAD FACTOR
SUNDAY	66·12 %
MONDAY	66·89 %
TUESDAY	68·45 %
WEDNESDAY	72·13 %
THURSDAY	71 59 %
FRIDAY	71·06 %
SATURDAY	71·06 %
FOR FULL WEEK	63 39 %

S. A. Gadkary

TYPICAL DAILY & WEEKLY LOAD CURVES.





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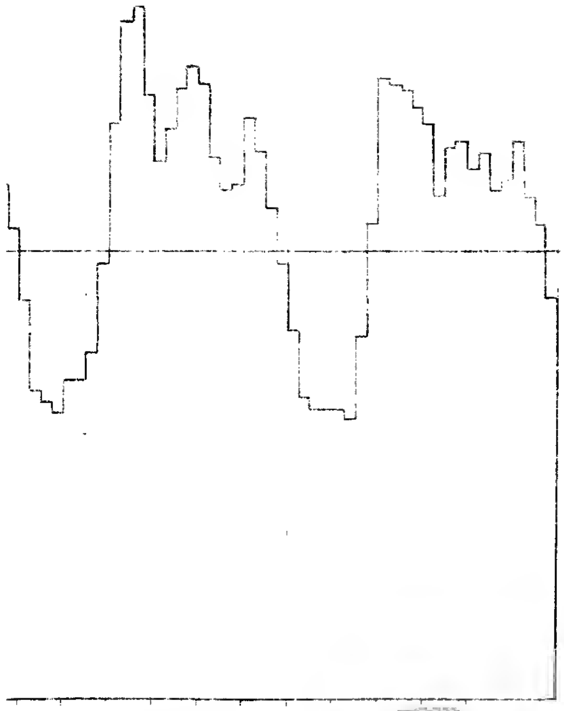
COMPARED BY:- Lachhman

Reg. No. 2822 HE'48-

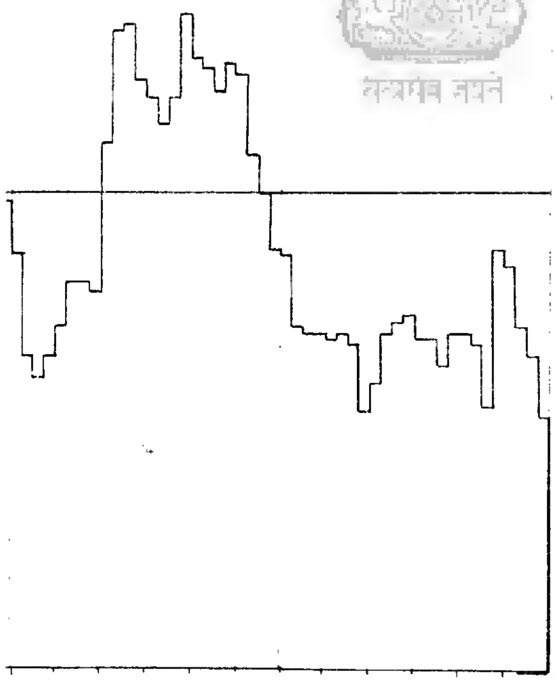
FIG. 4



DAILY LOAD FACTORS

DAY	LOAD FACTOR
SUNDAY	67.39 %
MONDAY	74.40 %
TUESDAY	72.54 %
WEDNESDAY	68.08 %
THURSDAY	74.48 %
FRIDAY	71.61 %
SATURDAY	76.09 %
FOR FULL WEEK	63.0 %

FIG. 5



DAILY LOAD FACTORS

DAY	LOAD FACTOR
SUNDAY	76.26 %
MONDAY	72.95 %
TUESDAY	72.29 %
WEDNESDAY	71.47 %
THURSDAY	74.11 %
FRIDAY	75.99 %
SATURDAY	78.89 %
FOR FULL WEEK	64.37 %

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FIG. 6

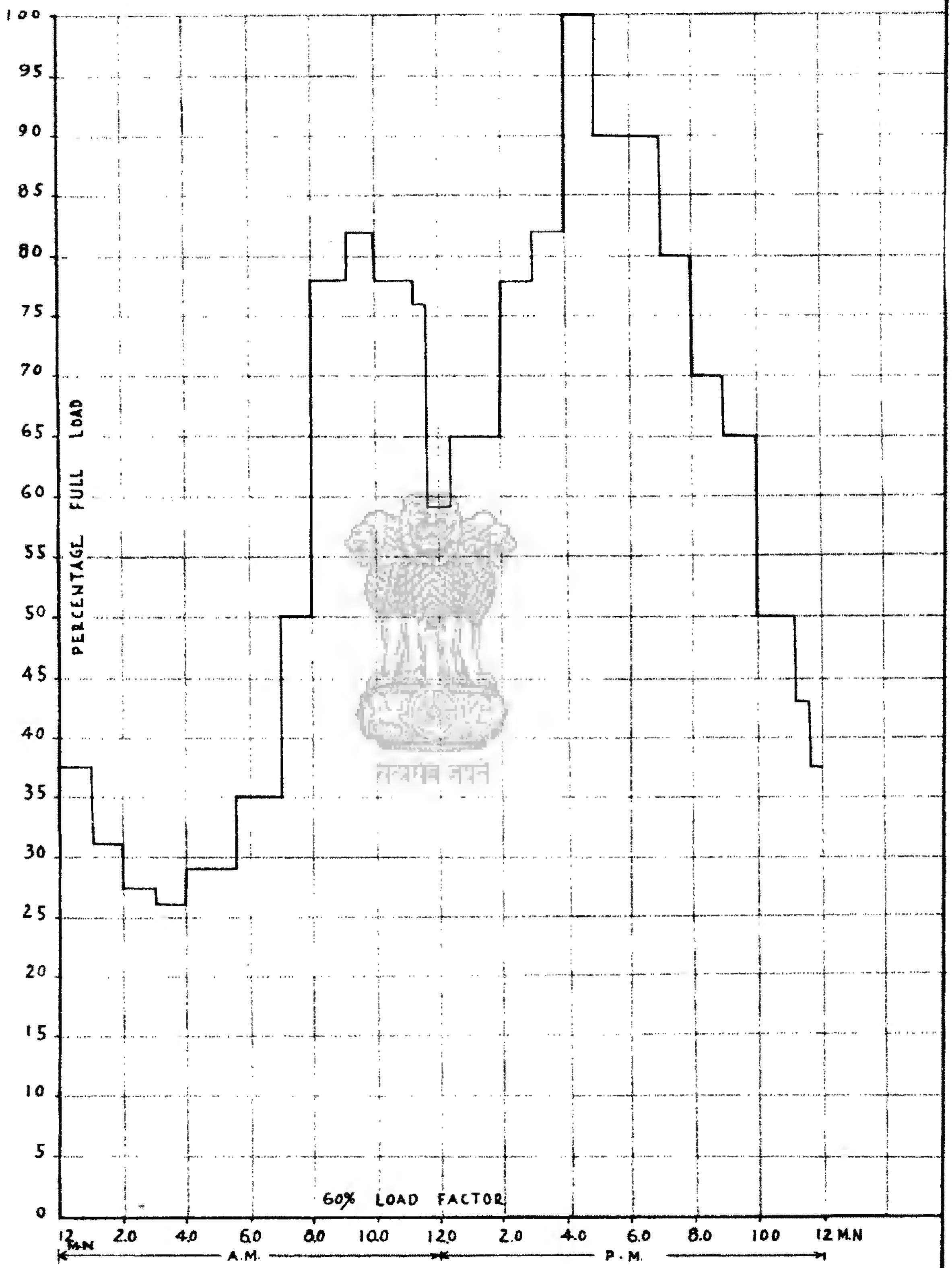

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FIG. 7

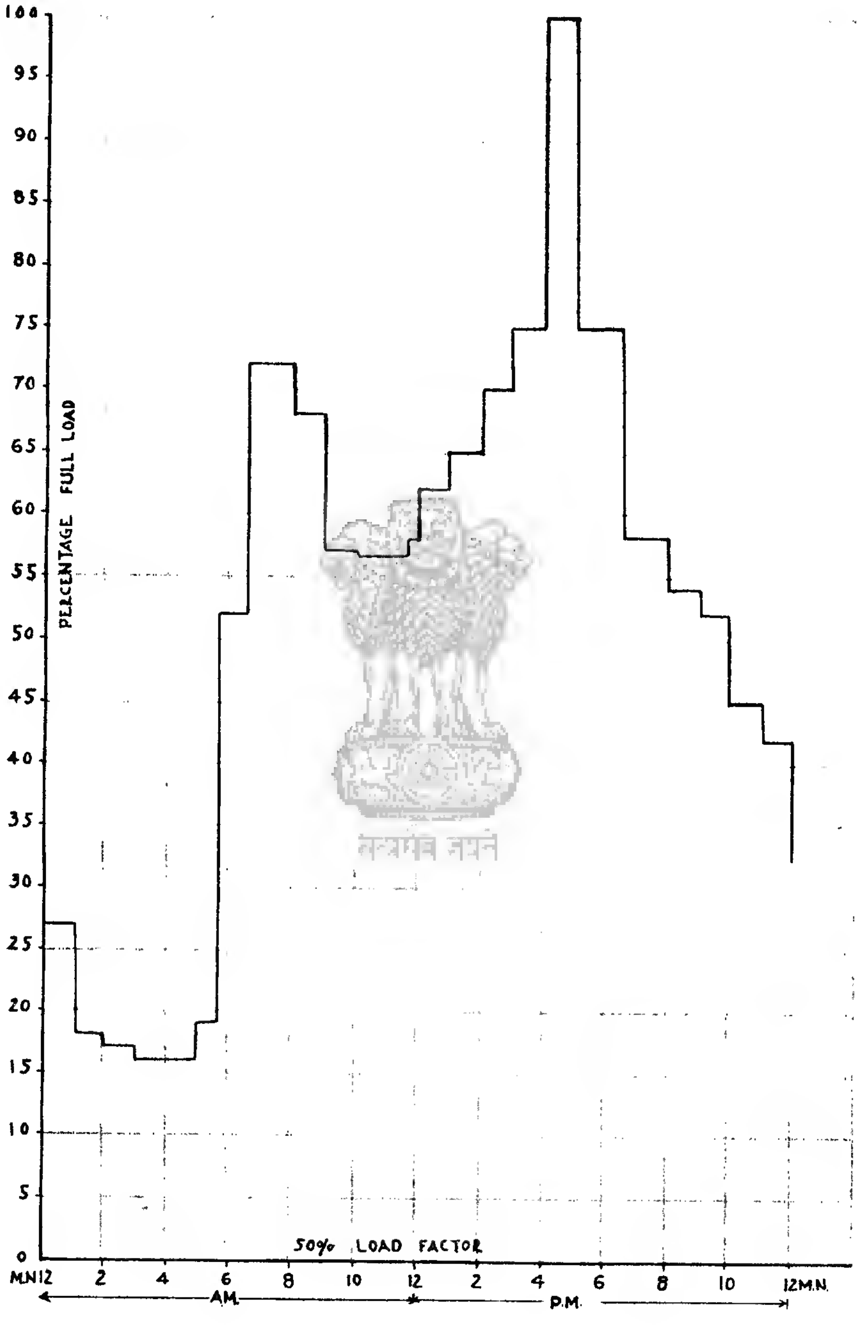

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FIG. 8

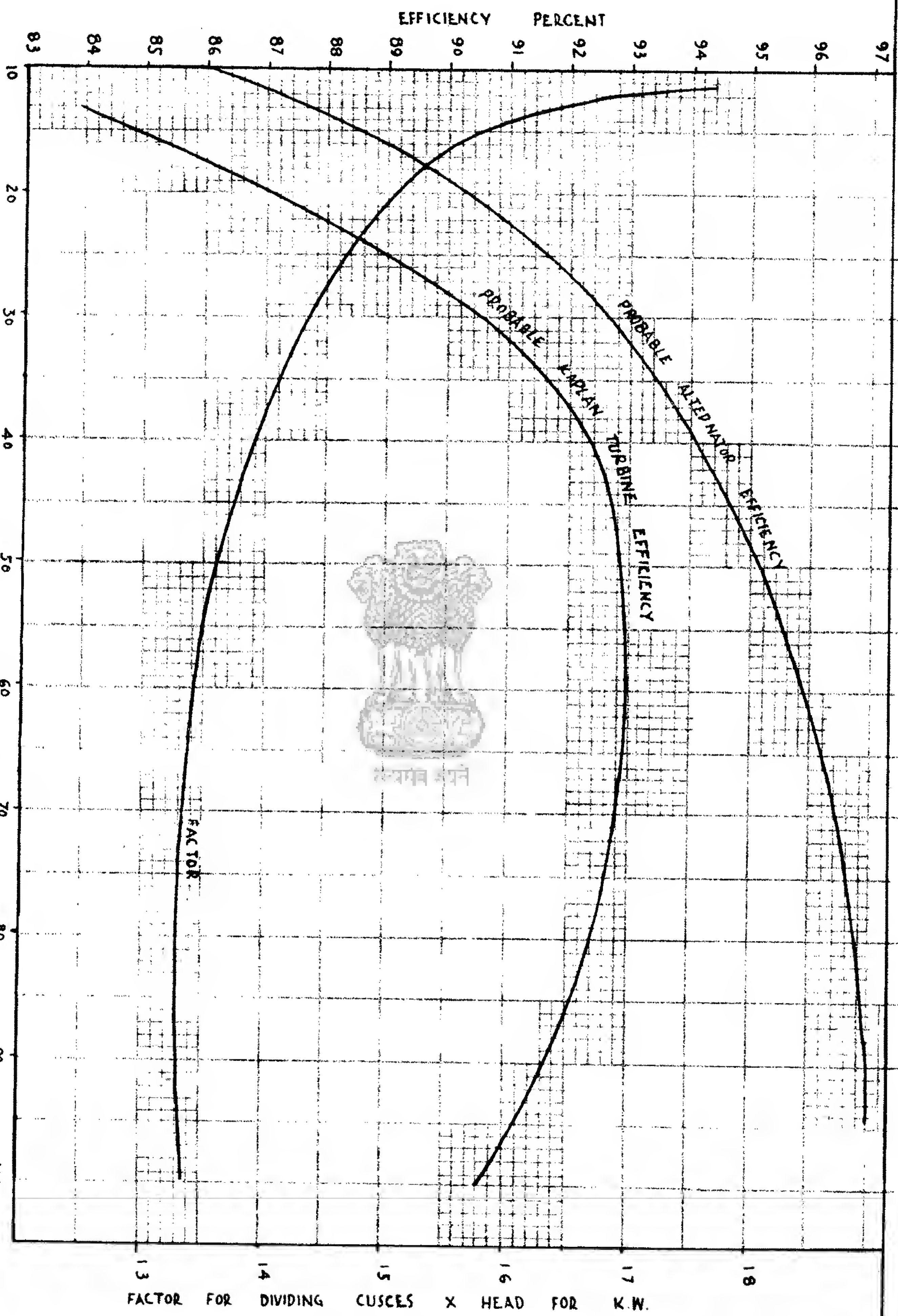

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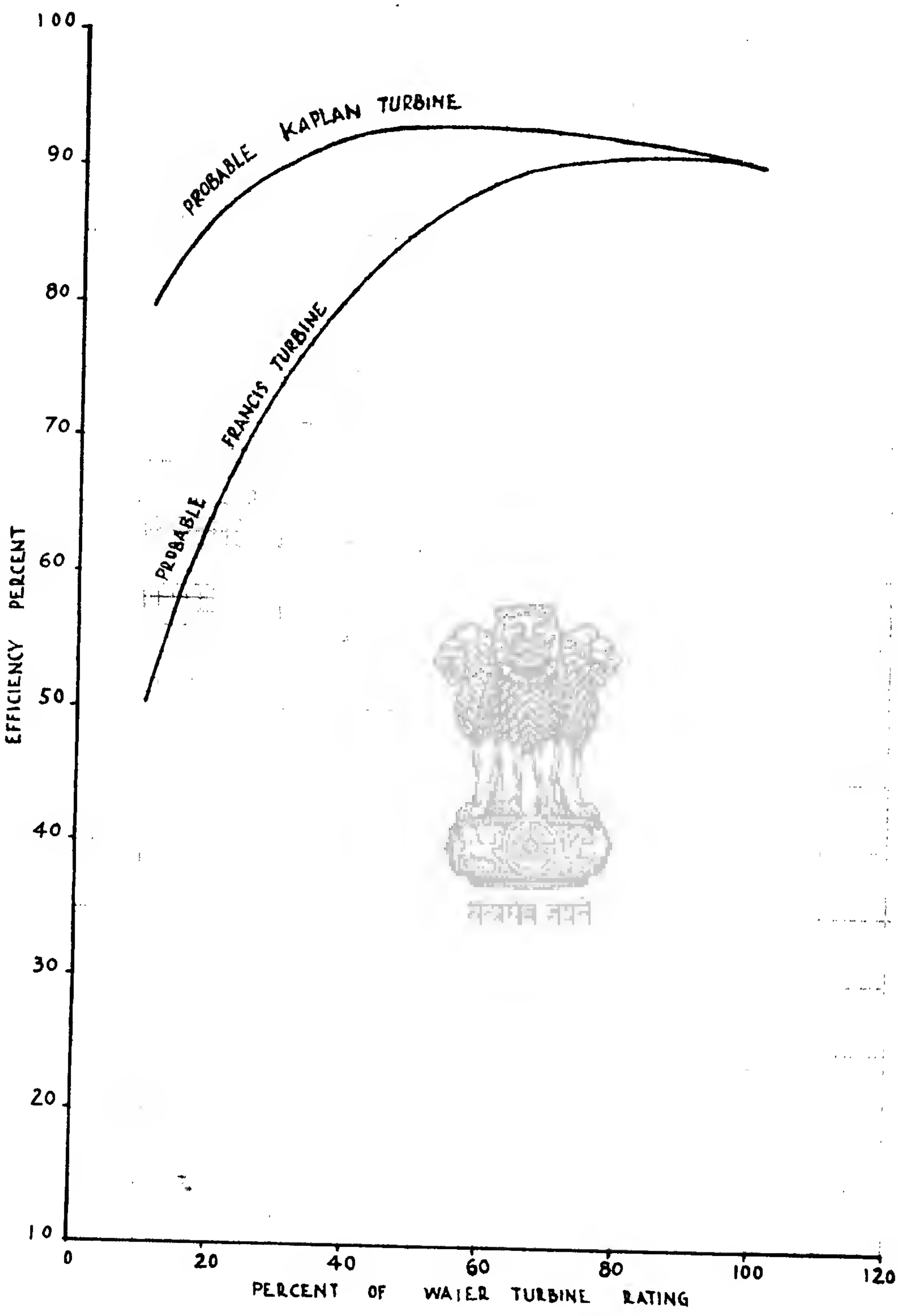
FIG. 9



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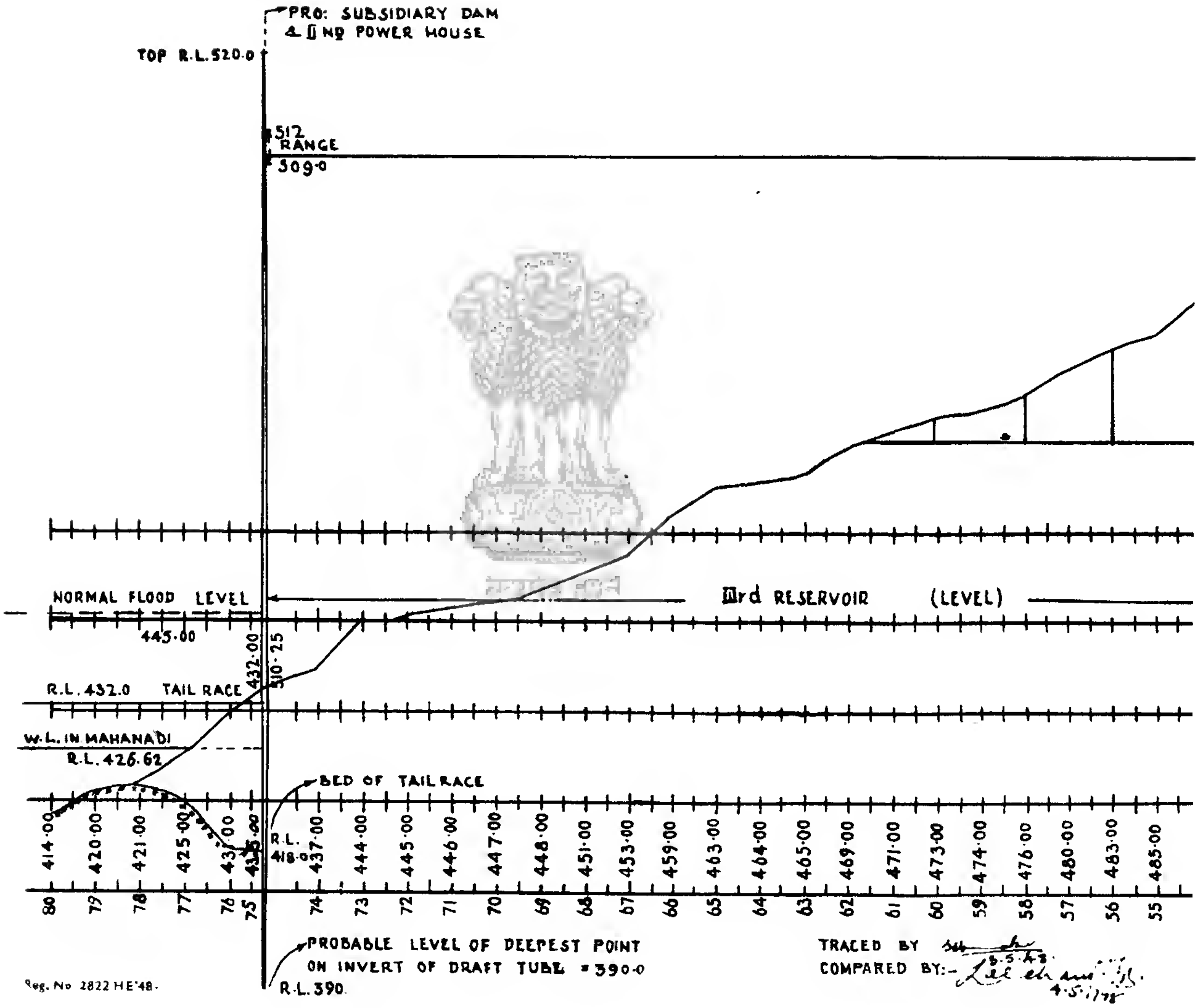
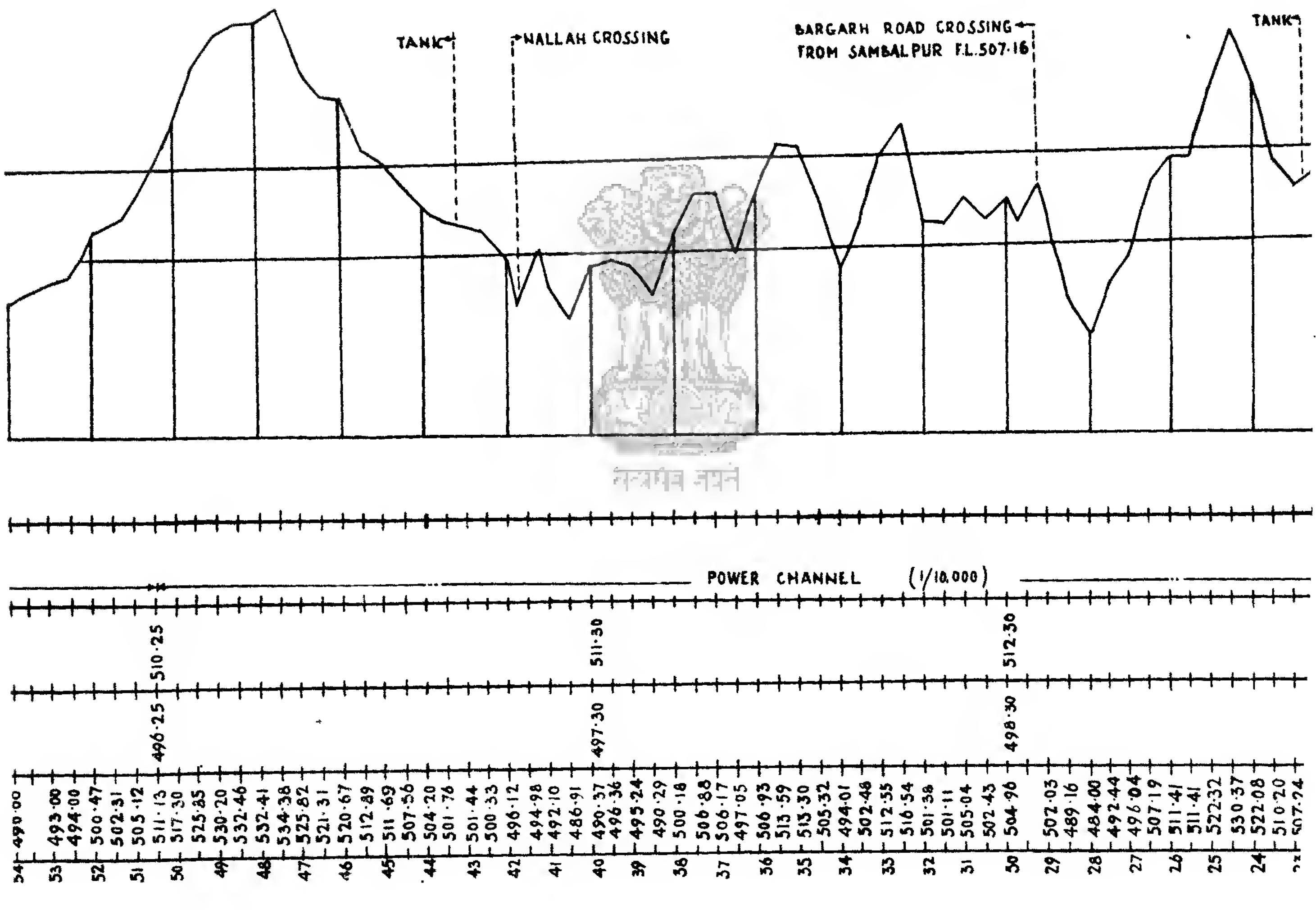

PRO: SUBSIDIARY DAM
& IInd POWER HOUSE
TOP R.L.520.0
512
RANGE
509.0
NORMAL FLOOD LEVEL
IIIrd RESERVOIR (LEVEL)
445.00
432.00
510.25
R.L.432.0 TAIL RACE
W.L. IN MAHANADI
R.L.426.62
BED OF TAIL RACE
R.L.
418.00
414.00 420.00 421.00 425.00 431.00 435.00 437.00 444.00 445.00 446.00 447.00 448.00 451.00 453.00 459.00 463.00 464.00 465.00 469.00 471.00 473.00 474.00 476.00 480.00 483.00 485.00
80 79 78 77 76 75 74 73 72 71 70 69 68 67 66 65 64 63 62 61 60 59 58 57 56 55
PROBABLE LEVEL OF DEEPEST POINT
ON INVERT OF DRAFT TUBE = 390.0
R.L.390
TRACED BY
COMPARED BY:-
Reg. No 2822 HE'48

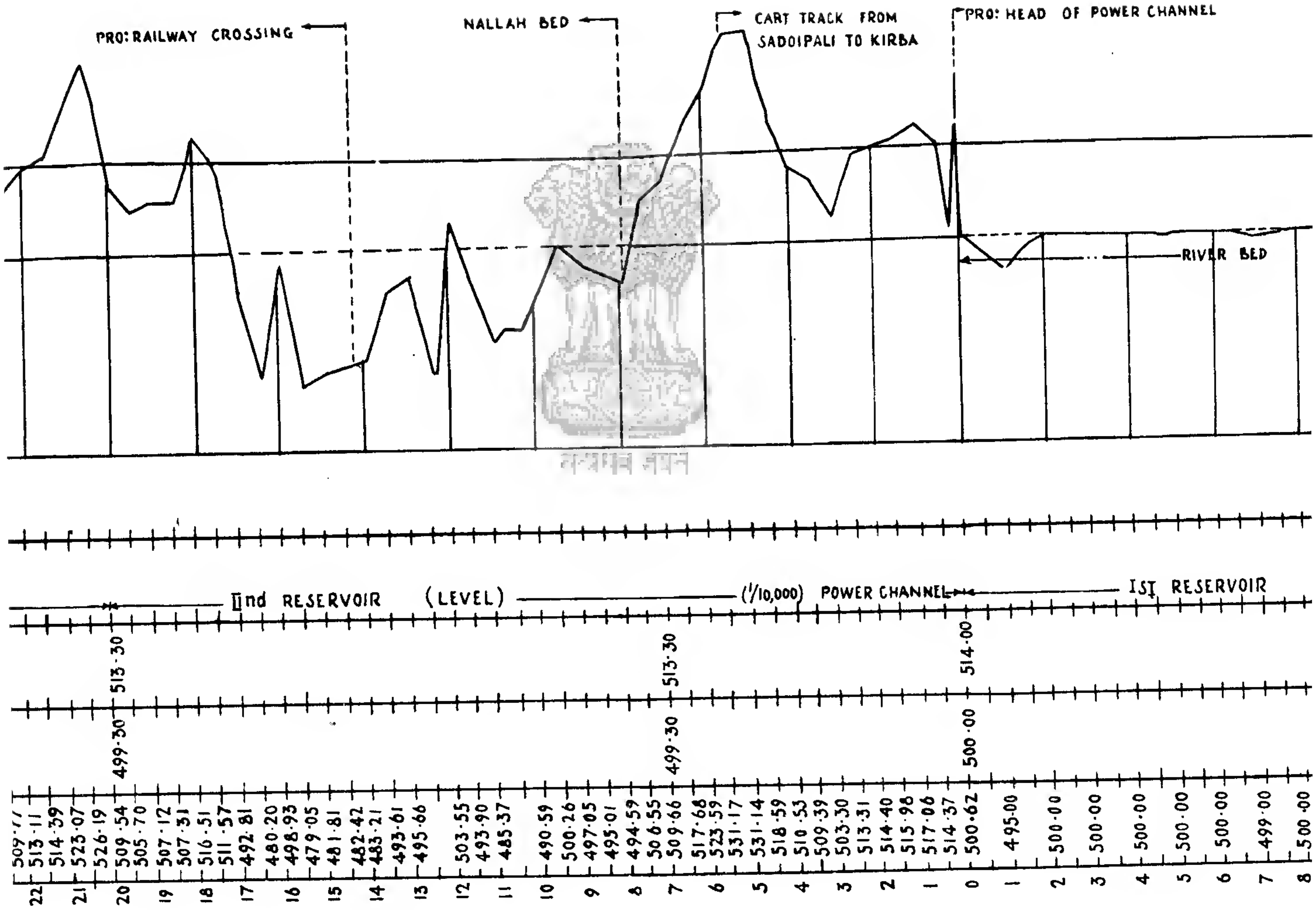
HIRAKUD DAM PROJE(

LONGITUDINAL SECTION OF POWER C

SCALE { HOR. 2" = 1 MILE
VER. 1/200



HANNEL



PRO: RAILWAY CROSSING
NALLAH BED
CART TRACK FROM SADOIPALI TO KIRBA
PRO: HEAD OF POWER CHANNEL
RIVER BED
IInd RESERVOIR (LEVEL)
(1/10,000) POWER CHANNEL
IST RESERVOIR
513·30
513·30
514·00
499·30
499·30
500·00